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SPONS'

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OF THE

INDUSTRIAL ARTS, MANUFACTURES,

AND

RAW COMMERCIAL PRODUCTS.

EDITED BY

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Graphite mining on private lands was subjected to a Royalty by the local government as early as 1851. The amount was then fixed at 4*s.* per ton of mineral raised, which was increased to 5*s.* in 1852, 7*s.* 6*d.* in 1859, 14*s.* in 1862, 16*s.* in 1864, and 30*s.* in 1869. In consequence of the difficulty experienced in collecting this Royalty, it was abolished in 1873, and was replaced by an export duty of 1*l.* per ton, levied by the Custom House on all graphite exported beyond the seas. This came into force on the 1st April, 1874. The quantity and value of graphite exported from Ceylon for seven years ending 1877 have been as follow:—1871, 125,257 cwt. (62,095*l.*); 1872, 136,051 cwt. (43,837*l.*); 1873, 173,996 cwt. (147,939*l.*); 1874, 149,938 cwt. (135,016*l.*); 1875, 110,023 cwt. (103,146*l.*); 1876, 117,361 cwt. (110,026*l.*); 1877, 96,792 cwt. (90,743*l.*). The mineral has also been recognized in Burmah, and has been contributed in small quantities from Vizagapatam and Malacca. The general Indian product is not sufficiently fine for pencils, but is available for crucibles.

Little as we know of the African continent, graphite has already been found in many parts of it. A very good quality is found to the south of Springvale, in Natal, in gneiss. As the working is not very expensive, a ton of pure mineral costing only about 30*l.*, hopes are entertained that it will pay to ship. Traces of graphite are met with at several points in the "old colony." A considerable deposit occurs not far from the mission station of Inyatin, about 20° S. lat. In Bamba Hill, Southern Usambara, Keith Johnston found it disseminated through the mass of the rock, a garnetiferous gneiss.

Graphitiferous rocks of the Laurentian system are widely spread throughout Canada and some parts of the United States. The graphite of these rocks usually occurs in beds and seams, varying in thickness from a few inches to 2–3 ft. They are often interrupted, giving rise to lenticular masses, which sometimes are nearly pure. The deposits generally occur in the limestones, or in their immediate vicinity, and granular varieties of this rock often contain large crystalline plates of graphite. At other times, the mineral is so finely disseminated through the limestone as to give it a bluish-grey colour, and the distribution of the stained bands serves to mark the stratification of the rock. The graphite of the Laurentian series is not, however, confined to the limestone.

Perhaps the most important and extensive of the Canadian deposits is that near the township of Buckingham. Here the graphite occurs both in beds or veins, and disseminated. The veins are fourteen in number, some 6–10 ft. wide, and 3–14 in. thick, besides more or less disconnected lenticular masses, yielding 30–35 per cent. of mineral. The vein graphite is of two varieties: (*a*) foliated: of dense, massive structure; made up of broad and thick laminæ; colour, dark steel-grey; lustre, metallic; sp. gr., 2·2689; carbon, 99·7, ash, 0·147, volatile matters, 0·178 per cent.; (*b*) columnar: carbon, 98·0, ash, 1·78, volatile matters, 0·594 per cent.; sp. gr., 2·2679. Second samples of each gave: (*a*) sp. gr., 2·2714; volatile matters, 0·109, carbon, 99·815, ash, 0·076 per cent.; (*b*) sp. gr., 2·2659, volatile matters, 0·108, carbon, 99·757, ash, 0·135 per cent. Besides this vein graphite, there is a quarry of the disseminated mineral, more than a ¼ mile long, and 70 ft. high, giving 10–60 per cent., the average being about 25 per cent.

The graphite is here prepared or "dressed" for the market in the following way:—The crude ore is stamped fine in water, and then put through buddles, by which the graphite and the rock matter associated with it are separated according to their specific gravities. The graphite is subsequently charged into reverberatory furnaces, and ultimately passed through bolters, whose gauze is of various degrees of fineness, according to the size required. According to Hofmann, the Canadian graphites equal those from Ceylon in point of incombustibility, and on that score are as well fitted for crucible making. On the other hand, all the samples examined contained more or less carbonate of lime and oxide of iron, both exceedingly objectionable in graphite intended for refractory purposes. By a process of treatment to be discussed further on, it is possible, however, to remove these and other foreign matters, so that "dressed" mineral showing 13–15 per cent. of impurities, may contain only 6·69 per cent. after treatment 5·35 of this amount being silica. In this way, the Canadian graphite can be rendered quite fit for crucibles, &c. Its cost price after dressing is about 3*l.*–5*l.* per ton. Workable deposits of graphite also occur in the Dominion, near the townships of Burgess, Lochaber, and Grenville.

There are two important graphite mines in the United States, the principal being the Eureka mine, near Sonora, California. The lode from which the mineral is obtained runs about 4000 ft. in a N.-E. and S.-W. direction, and ranges from 29 to 40 ft. in width. It is much broken up and mixed with the surrounding rock and earth to a depth of about 30 ft., but below this it is well defined between walls of sandstone and clay-slate. The lode is frequently divided by lenticular masses of clay-slate, from a few inches to several feet in thickness. A shaft sunk on the lode to a depth of 65 ft. showed the mineral to be purer and more solid than at the surface. The lode continues 25 ft. wide, and much of the mineral is so pure that a couple of men can extract and sack about two tons daily of a quality that can be sent to market without any preparation.

The apparatus used for separating the graphite from the impurities, when the mine was first opened, consisted of a wooden barrel, perforated with small holes, an iron rod passing through it lengthwise. The ends of the rod formed journals, which rested on two upright posts, the machine being turned by hand, by means of a crank, precisely like a barrel churn. The dirt to be washed being put into the barrel by means of an opening at the side, a small stream of water was led through a pipe to the top of the machine. After a few minutes' turning, all the graphite, sand, and fine grit were washed through the holes; the stones and lumps remaining in the barrel were thrown out at every charge. The water containing the finer materials was caught in a tank, about 5 ft. deep, placed immediately under the barrel, the only outlet from the tank being a shallow spout a few inches from the top. The graphite in exceedingly fine particles floated off in the water which passed over this spout, while nearly all the sand and other materials remained in the tank. The water holding the graphite in suspension was then passed through a series of shallow tanks made of board. After a " run " of several days, the water was let out of the shallow tanks, and the sediment they contained was left exposed to the sun for a few hours, when it became blackened ready for the market. That obtained from the last of the tanks was finer than that from the first, though all was extremely fine. An analysis made of some from the last tank gave 97·9 per cent. carbon. Nearly 200 tons were prepared in this way, and sold readily in New York, Philadelphia, &c., at 20*l.* per ton.

As operations increased, improvements were made. Iron cylinders worked by water-power were substituted for the barrel, the water and sediment leaving them being conveyed by pipes to a large tank made of planks and stout framing, and capable of holding 1000 tons. When this tank was filled (in about three days), its contents were allowed to settle for 24 hours, after which the dirty water was let off from the surface, and a powerful stream of clean water was let on, which forced the sediment through spouts into 18 shallow tanks, each 20 ft. wide, 25 ft. long, and 1 ft. deep. After remaining in these tanks about 3 days, the water was let off, and the sediment was exposed to the sun. In 24 hours it becomes hard enough to be taken out in blocks, which, after lying for another 24 hours on plank platforms, are ready for market. About 25–30 tons per week were treated by this method; but the demand still growing, arrangements had to be made for turning out 20–25 tons per day.

These consist of a sort of *arrastra*, or puddling-machine, to replace the cylinders, comprised in a circular bed 20 ft. in diameter, with water-tight sides 3 ft. high, in the centre of which is an upright post with 4 arms, to which are attached stirrers instead of grinders, as in an *arrastra*, it being desirable not to grind the mineral, only to separate the particles. It is driven by a water-wheel, and 15 Chinamen are employed to feed in the mineral. A small stream of water passing constantly through it carries all the lighter particles away. The rocks and sand are let out by a sluice-gate every 3–4 hours. The water carrying the graphite is conveyed by a flume to an enormous tank built in the ground, measuring 200 ft. long, 150 ft. wide, and 7 ft. deep, and capable of holding 30 days' collection. This was very expensive to construct, its entire inner surface being coated with a specially prepared cement, sufficiently smooth to prevent the graphite adhering, and so porous as to preclude its retaining moisture after the water had been let off. When the tank contains 3–4 in. of sediment, it is considered full, and, after standing for a few days, the water is run out, and the sediment is exposed to the sun. In two days, with fine warm weather, it is sufficiently dry to be taken out and laid on the drying-platforms, and in 24 hours is ready for market.

The cost per ton of the pure graphite needing no preparation, employing Chinese labour at 8 dol. a week, without board, is thus stated:—Extraction, 4*s.* 2*d.*; sacks, 8*s.* 4*d.*; land carriage to Stockton, 65 miles, 1*l.* 17*s.* 6*d.*; rail to San Francisco, 6*s.* 3*d.*; ship to Liverpool, 2*l.* 18*s.* 4*d.*; commissions, insurances, &c., 2*l.* 12*s.* 1*d.*; total, 8*l.* 6*s.* 8*d.* Its market value in Liverpool is about 20*l.* per ton. The output is about 500 tons per annum, nearly all of which is exported to Europe.

The second considerable American deposit is worked on the eastern slope of the " Black-lead Mountain " of the old maps of Essex County, New York State. The mountain lies just behind the village of Ticonderoga. The ore is mainly of the foliated variety, interspersed in veins among gneiss and quartz, with a dip of about 45°. Two analyses yielded 96·656 and 97·422 per cent. of carbon respectively. Some of the veins are much richer than others; one has been worked to a depth of about 350 ft., and found to be of varying thickness and with occasional pockets. After leaving the mine, the mineral is first crushed in an ordinary stamp battery to a fine powder, and the constituents are separated by Cornish buddles and settling-tanks. The graphite is then washed, dried in an oven, and bolted like flour, after which it is ground in water in a Bogardus mill, and again bolted. The grade thus produced is called " crucible stock " ; for finer grades, additional processes are necessary. The miners are paid at the rate of about 25*l.* per ton of prepared graphite. The five grades of manufactured graphite are estimated to be worth about 2½*d.* per lb. for stove polish; 7½*d.* for powder polish; 2*s.* 1*d.* for pencils; and 4*s.* 2*d.* for stereotype powder.

Another important mine is reported at Whitehall, in the same State.

Australia possesses valuable graphite deposits, near Moreton Bay; at Ballarat, a very pure vein has been discovered, 5 in. thick at the top of the drive to 18 in. thick at the bottom. In New Zealand, impure graphite occurs in the Carrick Range, Otago, in considerable quantities, sometimes 13 ft. thick. A seam of graphite runs along the eastern shore of Fairfax Harbour, New Guinea.

Rammelsberg gives the following comparative tables of some graphites:—

a. Loss by ignition.—Ticonderoga (New York), 3·85 per cent.; Ceylon, 2·56; Borrowdale, 3·80–5·08; Upper Jenisei (Siberia), 2·53; Tunguska (Sidorow), 1·77–2·38.

b. Earthy matters.—Ceylon, 1·28 per cent.; Borrowdale, 7·00; Upper Jenisei, 4·50; Tunguska, 6·53.

c. Combustibility in contact with fused saltpetre: completely combustible—Ceylon, sp. gr. 2·257; Borrowdale, 2·286; Upper Jenisei, 2·275; Upernavik, 2·298; Arendal, 2·321. Incompletely combustible—Ticonderoga, sp. gr. 2·17; Ceylon, 2·246; artificial carbon, 2·30.

The application of graphite to the manufacture of pencils (see Pencils), and of stove polish (see Blacklead), are sufficiently familiar, but it is used for other equally important purposes. It is now much employed as a lubricator for the steam cylinders of engines; about 120–180 grains of the fine, dry, pulverized mineral being introduced twice a day through the usual tallow box. It is found to be much superior to oil or grease. Enormous quantities are consumed in crucible making, and another wide application of the substance has been created by the electrotype process, it being used to coat the surfaces of wood, plaster of Paris, guttapercha and other non-conducting materials, so as to make them conductors.

Very erroneous impressions are still generally entertained concerning the commercial value of graphite, so much so that it is a common thing for the discoverer of a new deposit to believe himself possessed of an immensely valuable property, whereas the mineral may be all but worthless. The reasons for this may be sought in the high price of the renowned Borrowdale graphite, and the common error of supposing all graphites to be alike. As a matter of fact they differ most essentially, not only in chemical composition—for crude native graphite is not purely carbon—but also in physical constitution, necessitating the greatest care in purchasing the raw material, that it may be of a character in accordance with its proposed application.

The value of graphite depends largely upon the amount of carbon it contains, which is best ascertained in the following way. The pulverized graphite is dried at about 182° (360° F.), then placed in a test-tube 4–5 in. long and ½ in. wide, of hard glass. To this is added about 20 times as much well dried oxide of lead, and the whole is well mixed. The tube and its contents are carefully weighed, and then heated by the blowpipe flame till the mixture is completely fused and no longer evolves any gases. After this operation, lasting about 10 minutes, the tube is allowed to cool, and the weight is again ascertained. The loss in weight is carbonic acid, the oxygen of which has been taken from the lead oxide, while the carbon is all that there was in the graphite. For every 20 parts of loss there must have been 12 of carbon. In general it is sufficient to take 1 to 2 grammes of graphite, and 20 to 40 of oxide of lead. Touching other chemical peculiarities, it will be useful to observe that argillaceous matters, though they reduce the value of the mineral, are not prejudicial; but the presence of carbonate of lime, or oxide of iron, is very objectionable in graphite intended for refractory applications. Presently it will be seen how far chemical treatment can be made to overcome these drawbacks; but first of the physical differences.

On freeing graphite from its ash constituents, by means of grinding it very fine, and subjecting it to treatment with alkali at the point of fusion, aqua regia, and hydrofluoric acid, the so-called graphitic acids are produced. Graphitic acid thus obtained from amorphous graphite is a fine yellow, amorphous powder, which, when decomposed by heat, yields a black mass of great colouring and covering powers, exceeding those of the finest lamp-black. The same acid prepared in the same way from foliaceous graphite appears under the microscope to consist of foliaceous crystals, whose residue does not colour and has no covering property. The division of graphite into amorphous and foliaceous varieties is, therefore, of the greatest practical importance. When a lubricating or covering body is required, as in antifriction compounds, blackleading, electrotyping, &c., amorphous graphite must be chosen; but for metallurgical and refractory purposes, the foliaceous variety is preferable. Granular or amorphous graphite, which is often the purest, is of little use for crucibles; but, with suitable manipulation, produces the finest grades for electrotyping and fine pencils.

Among the graphites now in the market, it may be said that the supply for refractory purposes, blacklead, and antifriction, comes in a great measure from Bavaria and other parts of Germany, and from Ceylon. The graphite of Passau (Bavaria), so extensively used in apparatus subjected to great heat, contains only 35–42 per cent. of pure graphite, the residue being argillaceous. The better varieties for pencil-making are also principally of Bavarian and Bohemian production, and form the best substitutes for the renowned Cumberland mineral, which owes its value rather to the peculiar state of aggregation of its particles than to chemical purity, as it is much less pure than some of the Ceylon graphite which does not approach it in price. The value of the comparatively pure crystalline graphite of Ceylon and America, containing very small proportions of earthy matters, is placed at about 20*l.* per ton. The former is too fragile for pencils. That found in the neighbourhood of Ronda in Grenada, and near Malaga in Spain, is hard and difficult to grind.

It now remains to describe the process above alluded to by which impure and waste graphites may be rendered available for many uses. The graphite is first reduced to very fine powder, then compacted by moderate pressure, and enclosed in thin paper glued all over and pierced in one place by a small hole, to permit the escape of air when placed under an exhausted receiver. In this way, the air is removed; and the orifice is closed. Within 24 hours, it is subjected to pressure again, and the block formed is capable of treatment as a natural solid body.

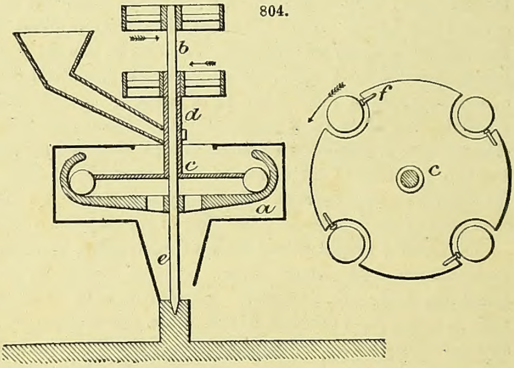
In order to remove the impurities from inferior graphites, the finely pulverized mineral is mixed with a proportion of nitric acid or an alkaline nitrate, chlorate, chromate, or bichromate, preferably chlorate of potash, in weight about $\frac{1}{20}$ to $\frac{1}{16}$ of the quantity of mineral. To this is applied sulphuric acid, sp. gr. 1·8, in quantity about equal to twice the weight of mineral, and the whole is thoroughly blended. The mixture, prepared in an iron vessel, is heated to a moderate degree, by which chlorous gas is copiously evolved. As soon as these fumes subside, the vessel is allowed to cool, and the oxidized and sulphated mass is thrown into water and washed by decantation. It is then dried, and heated to redness in a furnace, which causes it to swell up and disintegrate. The resulting powder has only to be agitated in water in order to separate the graphite, which is porous, and floats on the surface, from the silica, peroxide of iron, and other impurities, which, being heavier, sink to the bottom. The graphite thus prepared is absolutely pure.

The product obtained from amorphous graphite is not so fine as that from lamellar or foliated, and cannot be levigated with the same facility. To complete its purification, a little fluoride of sodium is added to the mixture in the iron vessel, as soon as the chlorous fumes cease to be evolved. The hydrofluoric acid, set free by the combination of the sodium with the sulphuric acid, immediately attacks the silica present, and carries off this impurity as gaseous fluoride of silica.

Ceylon graphite is very difficult to purify. After twice treating as above, there remained 0·42 per cent. of an incombustible residue, which was reduced by a third operation to 0·12 per cent. Bohemian and Styrian graphites purified in this way yielded mere imponderable traces of white incombustible matter.

For making crucibles, the first process which the graphite undergoes is that of grinding in "cannon-ball" mills, shown in plan and section in Fig. 804: *a* is a heavy iron saucer-shaped receptacle, having an aperture in the centre, across which are arms, connecting it with the central shaft *b*. This shaft is rotated by pulleys. Above the saucer, is a disc *c*, in which are four recesses. In these recesses, and resting on the saucer below, are four 32-lb. cannon-balls; and, attached to the middle of the disc, is a sleeve *d*, enclosing shaft *b*, and carrying a pulley, by which it is rotated in a direction relatively opposite to that of shaft *b*. A casing surrounds the mill, through which the graphite enters, emerging below through the funnel *e*, whence it is taken away by an elevator. When the graphite enters, the centrifugal force generated by the swiftly rotating parts throws it outward, so that it may be at once acted upon by the balls. Wear by the latter on the disc is prevented by steel pins *f*. It will be obvious that, under this condition, the heavier particles of the material will approach nearest the circumference, while the finer ones will arrange themselves in the order of their weights toward the centre. Consequently the finest ground graphite will always be that which is escaping from the mill, while the grinding parts constantly act on the coarser portion. In this way, the grinding operation is greatly facilitated, and, at the same time, the graphite is reduced to a degree of fineness unattainable in ordinary forms of mill.

804.



The graphite thus prepared is mixed with a small proportion of China-clay, varying according to the use for which the crucible is intended. To every 10 parts of graphite, is also added 7 parts of a grey clay which is imported from Klingenberg, in Bavaria, besides a little ground charcoal. These ingredients are mixed dry; water is afterwards added, and the compound passes to a cast-iron cylinder, capable of holding about 3 tons. Here thorough stirring is done by means of arms arranged radially on a central vertical rotating shaft. Each arm, besides having four vertical bevelled blades, is made flat above and bevelled below, so that the mass undergoes a kneading, which secures its rapid and homogeneous mixture. The material emerges in the form of thick mud, and is at once moulded either by hand or machinery, the operation being performed in almost exactly the same way as by potters. The same may be said of the subsequent baking. The above description applies more especially to the Dixon (American) crucibles. The Plumbago Crucible Co., of Battersea, mix Stourbridge clay with their graphite; their crucibles show, on analysis, 52·6 per cent. of carbon, 45·4 of earthy matter, and 2·08 of water.

The imports of graphite into this country, in 1873, were, from Germany, 2009 tons, value 28,964*l*.

(about 14*s.* 5*d.* per cwt.); Holland, 662 tons, value 11,390*l.* (about 17*s.* 2½*d.* per cwt.); Ceylon, 2500 tons, value 45,221*l.* (about 18*s.* 1*d.* per cwt.); other countries, 297 tons, value 7043*l.* (about 23*s.* 8½*d.* per cwt.).

(See Blacklead; Carbon; Gems—Diamond; Pencils.)

HAIR (Fr., *Crin, Bourre, Poil, Cheveux;* Ger., *Haar*).

Hair, a projection from the surface of the skin of many animals, consists of multitudes of slender, elastic, flexible, elongated cylinders, formed of fibrous, horny substance, and containing numerous cells, which, in coloured hair, secrete granules of pigment. The composition of hair may be stated approximately as:—Carbon, 50·65 per cent.; nitrogen, 17·71; hydrogen, 7·03; oxygen and sulphur, 24·61. The presence of sulphur is a notable fact, as it has an important effect on the action of dyes, and forms a ready means of distinguishing between animal and vegetable fibres (see p. 911). Hair, like feathers, hoofs, nails, and other modifications of the tegumentary system, when submitted to dry distillation, gives off products highly charged with carbonate of ammonia. The same remarks apply to wool as to hair. The chief distinction between these two products, if there be any save in name, lies in the fact that hair is generally straight, while wool is more or less curly and serrated. The scope of this article will embrace the hair afforded by all animals save the sheep, whose fleece will be described under Wool; while those hairs which have commercial value and use in their natural condition, attached to the animal's skin, are dealt with in the article on Fur. In the manufacture of leather, great quantities of hair have to be removed from the skins (see Leather).

The trade in hair is of no inconsiderable magnitude. Omitting the enumerated varieties, statistics of which will be given under their respective heads—alpaca, cow, goat, horse, and pig—our imports of unclassified hair in 1879 were of the following value:—From Russia, 45,134*l.*; China, 42,260*l.*; United States, 33,687*l.*; Belgium, 12,243*l.*; Germany, 11,703*l.*; France, 11,313*l.*; other countries, 9133*l.*; total, 165,473*l.* The exports of hair from Denmark in 1878 were 170,892 lb., value 216,327 *kroner* (of 1*s.* 1½*d.*); in 1879, 159,767 lb., 628,710 *kroner.* The exports of cow-, horse-, and pig-hair from Hamburg to Great Britain were 18,232 cwt. in 1876, 29,435 cwt. in 1877, and 28,656 cwt. in 1878. The exports of hair from Austro-Hungary in 1877 were 2344 metrical centners (of 110¼ lb.), value 460,808 florins (of 1*s.* 11½*d.*). Riga, in 1877, exported 43,740 *poods* (of 36 lb.), value 262,440 *roubles* (of 3*s.* 2*d.*). The exports of all kinds of hair from Canton were, in 1877, 665 *piculs* (of 133⅓ lb.); in 1878, 1076 *piculs.* The exports from Ceará (Brazil) in 1878 were 6827 kilo. to England, 460 kilo. to Havre, and 311 kilo. to Hamburg; and from Rio Grande do Sul, in the same year, 486,469 kilo.

The length, strength, and elasticity of hair render it useful for many purposes, varying according to its nature and origin. These will be alluded to under the head of each kind. The chief varieties of hair will now be separately considered.

Alpaca.—The name "alpaca" is somewhat indiscriminately applied to several allied hair-bearing animals, to the hair they afford, and to the goods manufactured from that hair. The genus includes four species—the alpaca or paco (*Auchenia paco*), the vicuña (*A. vicunna*), the llama (*A. lama*), and the huanaco or guanaco (*A. huanaco*).

The most important of these from our point of view is the alpaca. This animal, in size somewhat exceeding a large goat, ranges in its native condition from the centre of Peru into Bolivia, or between 10° and 20° S. lat. At and above an altitude of 8000–9000 ft., in the table-lands and mountain-ranges of the Andes, it lives in herds in a half-domesticated state, almost every peasant owning a dozen or so head. The animals feed principally on the *ichu*, a coarse, tall grass, frequenting the wild desolate spots below the snow-line, but have often to content themselves with mosses and lichens. They are driven in only at the shearing season. Their economic value lies primarily in their hair, and secondarily in their flesh, which latter resembles mutton, and is 3–4 times more abundant than that of the sheep. This species is not employed as a beast of burden. The fleece is superior to that of the sheep, both in length and softness. It averages a length of 7–9 in., and sometimes greatly exceeds these figures. It is very lustrous and fine, and is coloured mostly white, black, or grey, brown or fawn shades being rare. Each filament is straight, well-formed, and free from crispness, and the quality is uniform throughout, the fibre acquiring strength without coarseness. It dyes with facility, and takes the colours well. Its softness and elasticity are conspicuous, it spins into an even, strong thread, and textiles made from it have almost a silky lustre (see Woollen Manufactures—Worsted). The weight of the fleece reaches 10–12 lb., while 17 lb. is not an unknown figure.

The utility and value of the animal, which first aroused attention in 1836, led to many attempts to naturalize it in various parts of the globe. For some years, repeated efforts were made to raise flocks in this country, but they met with the ill-success that might have been expected from so great a change in the natural conditions surrounding the animals. That better results would attend a similar essay in the Highlands of Scotland seems probable. In the Pyrenees, a small herd did at one time exist, and there seems to be no good reason why the animals should not thrive there, and in other European mountain-chains, as the Alps, Carpathians, &c. In 1859, an attempt was made, on an extensive and costly scale, to introduce alpacas and llamas into New South Wales. For a time, all promised well, and the animals throve and multiplied; but by 1863, nearly all the old animals were dead, and the progeny, numbering some 350, several of which were hybrids between the alpaca and the llama, sickened and drooped, and in a short time numbered less than 200. Several of the survivors were purchased by other Australian colonies, and by New Zealand, but no care seems to have been able to compensate for the change from their mountain climate, and the experiment has ended in total failure. It has been proposed to repeat it in Natal, but the prospect there is not much more encouraging.

The vicuña is a much rarer and more valuable animal. Its geographical range in point of latitude exceeds that of the alpaca, as it extends throughout Peru and into Bolivia and Ecuador; but it seldom descends lower than 13,000 ft., and it is very wild, and sparsely distributed, in the district which it inhabits. It is somewhat smaller than the alpaca, and the weight of its annual fleece is but little over 1 lb.; on the other hand, the hair is exceedingly fine and delicate, varying in tint from a pale reddish-brown to a dirty-white, and usually brings double the price of alpaca for fine felting purposes.

The llama is larger than the alpaca, and is useful chiefly as a beast of burden and for its flesh. It inhabits only the loftier mountains of N. Peru. It affords a valuable fleece, which is, however, never shorn, and is almost entirely consumed locally, to the extent of 5–6 million lb., for sacking, cordage, carpets, and other coarse fabrics.

The guanaco attains almost to the size of our red deer, and is found from the equator to Tierra del Fuego, herds of 500 being met with in Patagonia. Its hair is dark-brown in colour, and shorter and coarser than that of any of the other species. It is worked up by the natives into blankets and ponchos, and rarely comes into this market.

Though the hairs afforded by these several animals are separately packed and marketed, the Board of Trade Returns do not distinguish them, but class them together, under Wool. In the first 4 years of the trade, our imports of all kinds were over 500,000 lb. annually, and the value was 10*d.* a lb.; in 1852, we imported 2,186,480 lb., value 2*s.* 6*d.* a lb.; in 1864, 2,664,027 lb.; in 1872, 3,878,739 lb., value 2*s.* 6*d.*–2*s.* 10*d.* In 1879, our imports were:—From Peru, 3,671,660 lb., value 230,284*l.*; Chili, 633,096 lb., 49,982*l.*; other countries, 21,027 lb., 1045*l.*; total, 4,325,783 lb., 281,311*l.* The exports from Mollendo (Peru) in 1878 were:—Alpaca, 1st class, 25,826 *quintals* (of 101½ lb.), 2nd class, 9691 *quintals;* vicuña, 216 *quintals.* In 1879, they were 29,416, 4631, and 203 *quintals* respectively.

Bison (*Bison americanus*).—The American bison, generally and erroneously called "buffalo," inhabits the prairies of America, from the eastern slopes of the Rocky Mountains to the Appalachian chain, and from 63° N. lat. to New Mexico. The hair afforded by the animal is spun and woven into gloves, stockings, gaiters, and largely into cloth for making overcoats. It is very strong and durable, and the fabrics have as good an appearance as those of sheep's wool. It is probable that much of the hair which figures in the Returns as elk's is really derived from the bison. The pelts of the animal, termed "buffalo-robes," measure 8 ft. × 12 ft., and are of dun-brown colour. The best come from the Saskatchewan. Prime ones are used as sleigh-robes, &c.; inferior are converted into mocassins, and form an excellent buff leather (see Skins). The value varies from 12*s.* to 40*s.*, and the number marketed yearly is about 100,000.

Camel.—The camel is of two species. The Arabian, "single-humped," or "dromedary" (*Camelus dromedarius*), is found in Arabia, India, N. Africa, and Asia Minor; the Bactrian, "two-humped," or common "camel" (*C. bactrianus*), is larger, more robust, and rarer, and occurs throughout the regions eastward and northward of the habitat of the former species, i. e. from the Black Sea to China and Lake Baikal. Both species occur in Central Asia. The under side of the neck, the upper part of the legs, and the humps, of these animals are covered with an abundance of woolly hair, exceeding sheep's wool in length, and varying in colour and quality, according to the species, and the climate under which it lives. The hair of the Arabian camel is thin, whitish, and fine; while that of the Bactrian is thicker, coarser, and darker coloured, and, in Tartary, is divided into three classes, according to its shade, black being the most highly prized, red next, and grey only half as valuable as red. The hair varies in quality from a fineness equal to that of silk, to a considerable degree of coarseness; in quantity, it commonly amounts to 10 lb. annually. In the spring, the animals cast this hair, which is called *koork*, or "down," and is little inferior in fineness to that afforded by some breeds of shawl goats, while it possesses the advantage of being much longer, and more easily separated. In the young animal, it is fine and smooth; but with age, it becomes curly and crisp. The animals are shorn every spring after the second year, and the hair is cleaned and assorted for home use, or exported in the raw state. The Arabs, and other Eastern nations, spin it and weave it into a kind of semi-waterproof cloth for wrapping merchandise, and into tent-coverings, shawls, and carpets. In Persia, very fine stockings are made from it, the white being most valued; and both in Persia and Tartary, a most durable, warm, soft and light cloth is made, patterns being produced by selecting the naturally coloured hair. Some 25 years since, the hair was already finding its way into European commerce. It was shipped from Smyrna, Constantinople, and Alexandria, and used chiefly by the French for making superior hats, and the longer hairs for making artists' pencils. In 1861, however, we received 322,000 lb. For a time, Russia almost monopolized the trade, quantities of the hair being shipped from Russian ports chiefly to London and Liverpool. The exports from Revel to Great Britain in 1878 were 6894 *poods* (of 36 lb.), and in 1879, 6793 *poods*. Much of this was re-shipped, especially to America. As the supplies increased, the coarser qualities began to be converted into carpets, and the better staples to be combined with wool for making winter garments. When the Chinese port of Tien-tsin was opened to foreign trade, camels' hair soon developed itself into a commercial specialty. The authorities levied an export duty of 5 per cent. *ad valorem*. The actual prices paid in 1877 ranged from 2 *taels* (of 6*s*.) a *picul* (of 133⅓ lb.) for the coarsest and dirtiest, to 16 *taels* for "finest recleaned," and 6 *taels* 5 *m*. was the value fixed as a basis for the tax. But in 1878, when the local prices ranged from 2 to 14 *taels*, the authorities increased the taxation standard to 10 *taels*, a step which cannot fail to check the growth of what promised to be a most lucrative trade for one of the poorest and most barren portions of N. China. The shipments from Tien-tsin (in *piculs* of 133⅓ lb.) have been:—in 1874, 3129½; 1875, 4070¾; 1876, 9824; 1877, 13,384¼. Shanghae, in 1878, exported a total of 11,788 *piculs*.

Cattle.—Cow- and ox-hair is afforded generally by the same countries as horse-hair, and the quantities produced in this kingdom are supplemented by large importations from abroad. Here it is principally used by plasterers, to increase the cohesiveness of their mortar, and in the manufacture of felt for roofing, sheathing, and packing purposes. Smaller quantities are employed in admixture with horse-hair for stuffing, and for making coarse friezes, blankets, rugs, and horse-cloths. In Germany, it is applied in carpet manufacture; and in Norway, the peasants convert it into hosiery. Much cattle-hair is obtained from the tanneries, where it is sold in the wet state at about 2*s*. 6*d*. a bush. Our imports (including the hair of the cow, ox, bull, and elk) in 1879 were as follows:—From France, 18,288 cwt., 16,742*l*.; Holland, 13,784 cwt., 10,968*l*.; Russia, 5772 cwt., 10,796*l*.; Germany, 5247 cwt., 5350*l*.; other countries, 8336 cwt., 11,343*l*.; total, 51,427 cwt., 55,199*l*. Riga, in 1878, exported 37,675 *poods* (of 36 lb.) of cow- and horse-hair, the former being valued at 8½ *roubles* (of 2*s*. 8*d*.) a *pood*. Santos (Brazil), in 1879, shipped 150 kilo. of ox-hair, value 8*l*., to Europe. The values in this market are about 13–14*d*. a lb. for cow-hair off the skin, and 11–12*d*. on the skin. White hair is much dearer than coloured. Plasterers' hair is worth about 5–8*l*. a ton; washed, 10–11*l*. Deer-hair is valued for stuffing saddles.

Goat (*Capra hircus*).—Two varieties of the domestic goat are valuable as hair producers—the Angora or Mohair, and the Cashmere. The mistake is commonly made of supposing them to be identical; but though they are only varieties of the same species (which includes at least four other varieties), their differences are such as to entitle them to separate consideration. Collectively, the goat ranks second only to the sheep as a source of hair or wool, and its fleece is the most important of those discussed in the present article.

Angora or Mohair Goat.—This useful animal is a native of the mountains and central plateaux of Asia Minor. The characteristics of the district where it attains greatest perfection are extreme dryness of climate, an elevation averaging 2500 ft. above the sea, and an abundant growth of oak (either trees or scrub), on the leaves of which, green in summer, dried in winter, the animals feed, maintaining themselves in good condition where grass-eating creatures would starve. The mohair-producing district is comprised within the following four towns:—Kastambol, near the Black Sea, in the north; Sivas, in the east; Konieh, in the south; and Eskishehr, in the west. More than twenty distinct and recognizable varieties of mohair are here grown, the differences arising from local peculiarities. The chief localities are as follows:—(1) Kastambol: its proximity to the moisture-laden winds of the Black Sea is prejudicial to the quality of the hair; the fleece, though lustrous, is hard and coarse; hence the error of selecting from this point animals for naturalization at the Cape, an error induced by the facilities for shipment. Passing southwards, the large province of Angora is divided into five separate districts—(2) Yabanova: yields a heavy lustrous fleece; (3) Tchorba: produces a mohair so soft and fine that it falls to pieces as soon as it is shorn; (4) Tchibúkova: its staple is remarkable for length and fineness; (5) Ayash: affords a white but lustreless variety; (6) Jeevar: the hair is bright and showy, but full of "stick," or kempy hair. The district of (7) Beybazar is remarkable for the hardiness and large size of its rams, some of which have been recently exported with good results. North-eastward lie (8) Tcherkes and (9) Geredeh: the animal has only of later years been introduced here, yet it has developed distinct traits from the differences of climate; the rams are very fine, and their fleece is so surcharged with grease as to appear almost black, but when scoured, it is second to none in quality. No animal has yet been exported from these two districts. Towards the east, are (10) Sivrihissar and (11) Eskishehr; here most of the goats perished by drought and famine in 1874–5, necessitating the introduction of fresh stock. Due south is (12) Konieh: the fleeces produced here assume the brick-red colour of the soil, and are of reduced value, though useful for special purposes; they are commonly known as "pelotons." This completes the tale of the chief districts within the quadrilateral before mentioned; but far to the eastward, on the Armenian and Mesopotamian frontiers, lies the province of Van, which has hitherto contributed large quantities of very inferior mohair, but having been devastated by the Russian invasion, will possess little importance in the immediate future. In Asia Minor, these goats are tended in flocks, varying from 200 to 5000 head, generally in company with sheep; this plan is found advantageous to the pastures, as the goats are more enterprising than the sheep, and, by breaking up the flock, prevent the latter cropping the herbage too closely. Turkish folds are of the most primitive kind, generally consisting of a sheltered spot enclosed by a low wall; they are little used except during heavy and continuous rain. When snow lies on the ground, as it does for two or three months, the surface is strewn with chopped straw or dried leaves for the animals to feed on. One goatherd, with a wolf-dog, can look after a thousand head, except in early spring, when the kids are born. The kids are singularly helpless during the first week of their lives, and the ewes show little maternal instinct; kids born in cold, wintry weather require shelter and indoor nourishment after nightfall. A running stream or good well is indispensable to a goat-run, as the animals drink frequently; an equally important precaution is to form a salt-lick, by placing lumps of rock-salt near the watering-place. No ordinary fence suffices to restrain them, and they are very great enemies to neighbouring cultivation.

The breeding of the mohair goat, and its cross-breeding with the common goat, has an important bearing upon future supplies of the hair. The best mode of commencing a flock is to secure a small but perfect selection of thorough-bred rams, to cross with the common ewe-goat. The rams of the second, third, and fourth districts mentioned above are undoubtedly thorough-bred, and, though smaller in size than some other varieties, possess all the points that a stock-breeder desires. In 5–6 years, a pure flock may be raised, limited only by the numbers commenced with. Of course the breed will not be absolutely pure, but practically every trace of under-breeding may be eliminated, and the mohair will be as fine and as long, though scarcely so abundant, as in the pure animal, while the silky lustre is increased. On the other hand, a constant infusion of pure blood is necessary to prevent deterioration. This is best accomplished by maintaining two distinct flocks: (1) a small flock consisting of 10 pure Angora rams, and 90 of the best of the ewes obtained from the cross, to be used as a feeder for (2) 100–200 of the cross-bred rams with as many common ewes as are procurable.

From 1866 to 1873, with a succession of fine seasons, the Asia Minor clip rose steadily from a total of about 30,000 bags (of 1½ cwt.) to nearly 50,000. In the summer of 1873, however, great drought reduced the animals to a miserable condition, and their starving state rendering them unable to resist the very severe winter that followed, nearly one-third perished, thus lowering the clip in the succeeding year to a little over 33,000 bags; of this, 25,000 were Angora qualities, 7000 Vans (which district did not suffer like the others), and 1300 pelotons. The goat-farmers, chiefly Turks, are for the most part both poor and improvident. They might have saved many of their flocks by timely provision, or removal to districts unaffected by the drought and severe winter; but the effects of this disaster, contrary to expectation, were not long felt, for the high prices obtained since 1874 led to extraordinary efforts to increase the number of goats. In 1876, the clip had again risen to about 38,000 bags of all sorts, brought about by extra care of the young, favourable seasons, and judicious crossing with the common goat. In 1877, the total clip was about 42,000 bags. In 1878, it was about 48,000 bags, composed as follows:—Angora qualities, primes, 35,000; inferiors, 3500; Van, 8000; Konieh, or pelotons, 1500. The mildness of the following winter gave promise of a still further increase to 52,000 bags.

The fleeces (*tiftik*) are clipped in April–May, according to the season, and yield an average of 1½–2¾ lb. of hair each. The best fleeces are exported by the Yurúks, who take great care to keep them clean. Van mohair contains on an average 70 per cent. of white hair, which, however, has a slight mixture of black running through it, and 30 per cent. of red and black, the whole much coarser in quality than the Angora sorts. Pelotons consist of 80 per cent. black and red, and 20 per cent. white, all of inferior quality, but containing a small percentage of hair finer than anything to be found in the Angora sorts. The finest hair of all comes from the first clip of the kid at its second year; one-year-old kids are seldom clipped. The second finest is from the she-goat, the next from the wether, the coarsest of all from the entire male. Inferior qualities come from crossing with the common goat, but the second cross brought to the pure male throws pure mohair. Woody and mountainous districts, with fir and oak, produce the best. Animals fed in the plains yield a quality with more kemps, and frothy, light, cottony fleeces. The male and female hair is very commonly united for the market, with the occasional exception of two-year-old she-goats' fleeces, which are kept with the picked hair of other white goats (perhaps 5 lb. being selected from 1000 lb.) for the most delicate native manufactures. The fleeces of surplus he-goats and barren females, killed at the beginning of winter, are 5–6 in. long. The skins are sold to curriers, who remove the hair by a preparation of lime, and employ the skins for slippers (see Skins). The hair thus obtained is harsher than that shorn from the living animal in spring, and is more or less damaged by the lime treatment; it is sold at a lower price as *deri* or "dead" hair. Some few skins are cured with the hair on; these bring 20*s.* each in Angora, and about 30*s.* in Constantinople, and are used in Europe as rugs and saddle-cloths. Formerly, and for a long time, we imported the hair only in a spun state (as "yarn"); but our textile manufacturers at length acquired the art of spinning it, and we now receive the raw hair alone.

The Angora goat is somewhat smaller than the common goat. The principal feature of all varieties of the breed is the length and abundance of its hair, covering the body and a great portion of the legs with closely-gathered ringlets, reaching near to the ground. The coat is composed of two kinds of hair: a short, coarse under-down, lying close to the skin; and a long curly overhair. Both are manufactured, but the latter is by far the more important in point of quantity and value. They are marketed together, and separated by the spinner (see Woollen Manufactures—Worsted). The value of the article depends upon its length, fineness, softness, brilliancy, elasticity, and durability. These qualities enable it to take the place of silk in the manufacture of velvets and laces, and to form the pile of imitation furs, besides being used for more general fabrics.

The export of Turkish mohair takes place chiefly from Smyrna, but Trebizonde also ships large quantities. The latter port in 1877 despatched 694 bales (of 1¾ cwt.), value 8328*l.* to Great Britain; in 1878, 440 bales, value 4400*l.*; and in 1879, 795 bales, value 7950*l.* Aleppo also, in 1878, exported 292 tons, value 46,720*l.*, to Turkey; 82 tons, value 13,120*l.*, to Great Britain; and 2 tons, value 320*l.*, to France. Alexandretta, in 1879, exported 112 tons, value 17,920*l.*, to Turkey; 71 tons, 11,360*l.*, to England; and 2 tons, 320*l.*, to France. The exports from the vilayet of Van, in 1879, were valued at 10,000*l.* Turkish. The productive capacity of Asia Minor is limited to about 60,000 cwt. of good or fair quality, and 15,000 cwt. of inferior. But the climatic and other conditions here prevailing are to be found in many portions of our African and Australian colonies. The goat succeeds admirably on land which will not support any other animal with profit. In the Cape, it is found that where sheep have been grazed, there springs up a *Mimosa*, which the sheep will not touch, but which affords excellent food to the goats. It is estimated that there are already about a million of these goats in the Cape Colonies, where the breeding is making rapid progress. The Transvaal seems to be admirably suited to them. But the Cape mohair is different from the Turkish, inasmuch as it is more kempy, and the kemp runs further to the top, while it is also shorter. On the other hand, it is quite as fine, and may be kept so by repeated infusion of pure blood. Mohair only began to figure in the Cape exports in 1862, the quantity then being 1036 lb.; in 1871, it increased to 536,292 lb., value 43,000*l.*; in 1875, it advanced to 1,147,453 lb., value 133,180*l.*; and in 1877, it amounted to 1,433,774 lb., value 116,382*l.* Great attention has been paid to the naturalization of the Angora goat in the United States, and the flocks there are now estimated to number nearly 2 millions. The first attempts were made in Kentucky and Georgia, more than 30 years ago, while the Pacific States have been selected for more recent experiment. The animal appears to flourish best upon the wild sage, on the desert plains of Nevada, and the fleeces become fine and silky. Yet the breeding of the goat for its fleece must be accounted at least a temporary failure in America, inasmuch as there is no local manufacture of the staple, and it will not pay to export at present prices. The rearing of the goat is attracting stock-growers in many parts of Australia, where the animal thrives well, especially on well-watered undulating prairie. In sandy districts, the hair is inferior, and soon falls off. Shearing is performed twice annually, when the fleece is about 6 in. long. This prevents its being torn and wasted. Each clip from full-grown animals is estimated at 4 lb., value 4*s.* a lb. The Fiji Islands are likely to become producers of mohair of excellent quality. The first considerable sample of Angora hair from Fiji was pronounced to be well grown and of good texture, and sold at a high figure. It was the produce of a small flock of goats bred on the Ra coast, and was declared to be almost equal to the best Turkish mohair. The flock has been raised from a small number of pure Angora goats, by judicious crossing. It now contains several hundred well-grown animals of 2nd–4th cross, the latter producing as much as 4 lb. of hair each, equal to the finest hair from the pure Angora goat. The climate seems admirably suited to the goat, and to the production of a good crop of hair.

Cashmere, Thibet, or Shawl Goat.—This variety of the domestic goat is considerably larger than the Angora kind. Like the latter, its coat is composed of two materials, but it is the undergrowth that here forms the commercial article. It is beautifully soft, silky, and down-like, and of a pretty uniform greyish-white tint. Its removal is effected by clipping and combing, the process occupying 8–10 days. The quantity obtained seldom exceeds ½ lb. It is sold by the *turruk* (of 12 lb.). The overhair is of various colours, lengths, and qualities. There are several modifications of this breed, and they are widely distributed in Asia. The best are produced in Cashmere, Thibet, Mongolia, and the Himálayas. Those of the hilly tracts of Khorassan yield a fine soft hair, generally of a more or less intense brown shade, while the long overhair is usually jet-black. The best are said to be among the Hazaree and Timunee tribes. Two fleeces are afforded annually:

the first grows during winter, and is shorn in spring; the second appears in summer, and is gathered in autumn. The latter is the finer and more esteemed. White fleeces are rare. The winter fleece is shorn off with the overhair, and is cleansed for making shawls, while the overhair is converted into grain-bags, tent-covers, and ropes. The autumn fleece is only taken from dead animals. The skins are rubbed with a preparation of lime and potash, and left for 2–3 days; the overhair is then easily pulled out, and the undercoat is subsequently removed separately. This is dearer than the winter fleece.

Turkestan goat-hair is sent in considerable quantities to Amritsur, in the Punjab. The best quality is procured in the immediate vicinity of Bokhara, and in the N.E. districts of that kingdom. It is used in combination with Thibetan hair for making Cashmere shawls. The white is most valuable; light-brown is the predominating hue; black and ashy-grey are packed separately. The hair is shed by the animals in summer; sometimes it is shorn; but most of it is taken from dead animals. Cabul hair is generally darker than that from Turkestan, and is shorter in staple. It is chiefly obtained from the hill country to the W. of Cabul, and between that city and Herat. Its value is only half that of the Bokharan. Considerable supplies are afforded by the Kirghiz Steppes and W. Thibet, whence the hair is taken to Rodokh. Another large portion is carried to Leh. The goats are very common in the provinces of Ladakh, Rodokh, Garoo, and the Chanthan plateaux. It is the produce of these goats which is chiefly converted into shawls in the Punjab towns. The very superior quality grown in Turfan Kechar is taken through Yarkand to Cashmere, and there manufactured. Closely allied breeds of the Cashmere goat are common in the countries west and south of the Caspian. The shawls of Kerman, in Persia, are but little inferior to those of Cashmere; and much of the hair produced in that country is carried to Amritsur, for the manufacture of so-called Cashmere shawls. The Persian and Armenian hair is also largely manufactured into Persian carpets. Attempts to naturalize the animal in France and England have been complete commercial failures. Some French experiments in crossing the Cashmere and Angora goats gave promise of an increased and improved fleece, but the unsuitable climate of France would doubtless soon cause deterioration.

Common Goats.—The common domestic goat is found in most countries of Europe, in Morocco, Algeria, India, the United States, and the Argentine Republic. Recent statistics give:—Spain and Portugal, 6 million; Greece, 2¼; France, 1¾; Germany, 1¾; Italy, 1¾; Russia, 1¼; Austro-Hungary, 1¼; United Kingdom, 1; British India, 6; Morocco, 12; Algeria, 3½; United States, 2½; Argentine Republic, 1¼. In all these countries, the hair, which varies much in colour, length, and quality, is industrially employed. In England, it is largely used for low-class carpetings. Mogador, in 1878, exported 22 cwt., value 35*l.*, to France; and Tangier, in the same year, shipped 238 cwt., value 428*l.* (including horse-hair), also to France. Shanghae, in 1878, exported 6273½ *piculs* (of 133⅓ lb.). The skins of common goats are of more importance than the hair (see Skins).

Imports of Goat-hair.—Our imports of goats' hair, without reference to the description, in 1879, were as follows:—From Turkey, 5,987,276 lb., value 541,812*l.*; British Africa, 2,102,019 lb., 138,178*l.*; France, 1,070,451 lb., 24,048*l.*; China, 343,062 lb., 20,564*l.*; other countries, 569,892 lb., 19,013*l.*; total, 10,072,700 lb., 743,615*l.*

Horse.—Though horse-hair is produced to some extent in almost every part of the world, commercial supplies are obtained chiefly from Russia, Germany, Belgium, several of the S. American States, and Australia. The small quantity obtained from English stables—the combings of manes and tails—is superior to any that is imported. The next in quality comes from Australia and S. America, generally yielded by healthy, vigorous animals. The worst, especially in point of dirtiness, and the presence of contagion, is procured from Russia, and in great part from Siberia. Foreign hairs reach this market packed in bales of strong cloth. The S. American bales are very large, sometimes weighing half a ton, and are bound with hoop iron, after having been subjected to hydraulic pressure. In all but the Russian bales, the mane hair and tail hair is packed in the same bale. The Russian bales are only about one-quarter the size of the S. American, and, being packed by hand, are relatively much lighter; they have also an external covering of the matting which is made in such large quantities by the Russian peasantry, from the bast of the linden tree. The Russian hair is gathered from all available sources by the peasants, who sell it in small parcels at the fairs to dealers, by whom it is made up into larger parcels for sale to the resident merchants. Thus, the "raw" hair which reaches the merchant is the mixed produce of innumerable places. At St. Petersburg, this raw hair is assorted, the long hair being made into "dollies" or bundles, more or less sophisticated with bunches of short hair, to make weight.

Our imports of horse-hair in 1879 were as follows:—From Germany, 6268 cwt., value 42,571*l.*; Argentine Republic, 4839 cwt., 23,165*l.*; Uruguay, 3110 cwt., 18,967*l.*; Belgium, 2869 cwt., 13,341*l.*; Russia, 888 cwt., 8901*l.*; other countries, 1608 cwt., 8019*l.*; total, 19,582 cwt., 114,964*l.* In 1875, the quantities were:—Germany, 7299 cwt.; Uruguay, 4935; Argentine Republic, 3069; Belgium, 1556; Brazil, 996; Australia, 906; Russia, 708; other countries, 762. The exports from

Poti in 1877–8 were 42 *poods* (of 36 lb.). From Riga, in 1878, were shipped 37,675 *poods* (including cow-hair). The shipments from Revel to Great Britain were 3435 *poods* in 1878, and 240 *poods* in 1879, principally tails. Tangier, in 1878, exported 238 cwt., value 428*l.*, to France (including goat-hair); in 1879, the figures were 98 cwt. to Great Britain, and 154 cwt. to France. The average annual shipments from Rio Janeiro are about 10,000 cwt., and from the Argentine Republic, 9000 cwt., much of which goes to the United States. Shanghae, in 1878, exported 292 *piculs* (of 133⅓ lb.). The market values are approximately as follows:—S. American, 4*d.*–1*s.* a lb.; ditto, good to fine, 1*s.*–2*s.* 6*d.*; Russian, 8*d.*–2*s.*; white tail, 11*d.*–4*s.*; black tail, 10*d.*–3*s.*; mixed, 9–14*d.*; short, 4–8*d.* The long hair is employed chiefly in making hair cloth, for covering purposes; also in other textiles, as stiff petticoats, and straining-bags and cloths; and for stockings, gloves, plumes, wigs, fishing-lines, and ropes. The short hair is curled for stuffing seats, mattresses, &c.; while medium coarse hair is sometimes used in brushes.

Human.—Women's tresses have of late years been important articles of merchandise. Scarcely any but "combings" is produced in this country, and supplies come chiefly from Continental Europe, India, and China, while even Iceland is not left unvisited by the itinerant hair-merchant. In S. France, the peasant-girls cultivate their hair with a commercial object. The light-coloured hair comes principally from Germany, Austria, and Scandinavia; the dark, from S. France and Italy. Indian and Chinese tresses are very coarse; yet the shipments of the latter, mostly to France, have risen from 286 *piculs* (of 133⅓ lb.) in 1871, to 11,254 *piculs* in 1875. The value varies according to length and colour. A length of 8 in. commands about 1*s.* an oz., while 36-in. hair may bring 30*s.*; and above 36 in. the prices are fanciful. The standard is 18 in., but 5–6 ft. is occasionally met with. Auburn, grey, light, and pale, are considered extra colours, and fetch much higher prices than the ordinary hues. The best hair is obtained from the living subject; dead hair is very inferior. The weight of a French head of hair (female's back-hair) is about 5 oz.; Italian, 6 oz.; German, 10 oz. The last are seldom marketed in their natural state, but are mixed to hide inferiorities. The tresses from Italy and Brittany require much cleansing. The chief use of human hair is for the manufacture of wigs and false tresses. The latter are the more important, and the fashion which governs them rules the market values. The United States ladies are probably the largest customers for the article. The Chinese hair is in demand among Americans of mixed African descent.

Pig-hair, or Bristles.—The hair which grows on the back of the pig commonly goes by the name of "bristles." The best are the produce of the wild hog, and the quality deteriorates in direct proportion to the degree of cultivation of the animal. Russia supplies the largest quantity and of the best quality. Siberia, and the district of Sarapoul, in the government of Wiatka, are noted for the best. Superior descriptions are obtained from the pigs which are fed on the refuse of the tallow manufactories. The Russian exports of bristles in 1877 were 139,836 *poods* (of 36 lb.), the largest quantity for 12 years, but, on the whole, they are declining. Revel shipped to Great Britain 1057 *poods* in 1878, and 714 in 1879. French bristles have the highest reputation in the market, being white, soft, firm, and elastic. The product is estimated at about 2 million lb. annually. German bristles (which include large quantities of Russian, sent landwise to German ports) are the dirtiest. Servia grows enormous herds of pigs; so also do Hungary and Roumania. These countries probably contribute not a little to the shipments from German, French, Dutch, and Belgian ports. American pig-hair is procured chiefly from the pork-curing establishments of Cincinnati and Chicago. The Chinese port of Shanghae shipped 681 *piculs* (of 133⅓ lb.), in 1878.

Bristles are assorted according to length and colour, and are tied in separate bundles, with the root-ends together, and packed in barrels. At Königsberg, they are classified as 1st and 2nd grey crown, 1st and 2nd white crown, white and grey shoemakers', and white and grey long. The best and dearest are those for cobblers' use; the others are made into brushes of various grades; while a few are employed for stuffing. The price ranges from 1*s.* to 7*s.* a lb., and is always advancing, while the supply decreases. Our imports in 1879 were:—From Russia, 708,694 lb., value 106,998*l.*; Germany, 556,934 lb., 89,145*l.*; China, 98,923 lb., 12,592*l.*; United States, 94,886 lb., 10,110*l.*; France, 75,351 lb., 12,065*l.*; Belgium, 41,525 lb., 4766*l.*; British E. Indies, 33,841 lb., 5314*l.*; other countries, 24,431 lb., 3398*l.*; total, 1,631,585 lb., 244,388*l.* In 1853, we imported 3,237,059 lb.

Yak (*Poephagus grunniens*).—This animal, found in Thibet, China, Mongolia, &c., is covered with a coat of very long hair, and has a long, bushy tail. The prevailing colour is black, but several other tints occur. The hair is much finer than horse-hair, and is locally employed for making strong ropes. It is occasionally exported to Europe.

Bibliography.—W. Walton, 'The Alpaca' (London and Edinburgh: 1844): T. Southey, 'Colonial Wools' (London: 1852); P. L. Simmonds, 'Animal Products' (London: 1877); G. Gatheral, 'The Angora or Mohair Goat' (Proc. R. Col. Inst., vol. ix., London: 1877–8).

(See Brushes; Feathers; Fur; Hair Manufactures; Leather; Skins; Wool; Woollen Manufactures—Worsted.)

HAIR MANUFACTURES.

Since the beginning of the present century, hair, as distinguished from wool, has been largely manufactured. The chief sources of supply of this class of fibre are the group of animals represented by the alpaca, the caprine tribe, the camel, the horse, the ox, and the hog. The chief of these, however, are used so entirely in combination with, or subordinated to, wool and other fibres, or their processes of treatment are so nearly identical with those of the latter, that a description of them will come more naturally under the divisions in which these articles are treated (see Woollen Manufactures—Worsted). Of the above, therefore, it is necessary only to notice the applications of the hair of the horse, the ox, and the hog, and the processes of manufacture through which they pass. The hair from these animals occupies a distinct place in our industries, and is not subordinated in such a degree as to lose its identity.

The bulk of the hair obtained from these sources is used for upholstery purposes, being manufactured into "curled hair" for stuffing, or hair cloth for seating. The raw material (see Hair) is roughly classified into English and foreign, the former being regarded as the best in quality. Each class is divided into several qualities, according to the purpose for which it is destined. The best English hair is that denominated "hard hair," consisting chiefly of hair obtained from ostlers and stablemen, being tail hair procured in combing. That similarly got from the mane is of a different quality, being termed "soft." Knackers' hair, or that obtained from dead animals is much inferior, "dead" hard hair not being more than equal to "live" soft hair. The depreciation which hair undergoes on the death of the animal is such that, when worn-out horses are sent to be slaughtered, the knacker always cuts off the mane and tail previously to the operation.

Horse-hair makes by far the best curled hair, but is not the only sort employed. Cow- and hog-hair constitute a large portion of that which is manufactured into curled hair for upholstery purposes. The former is chiefly procured from home sources, whilst of the latter the greatest proportion is imported from America, the supply from the continent of Europe having been neglected for several years, owing to the superior quality of that obtained from America. The hogs of the United Kingdom, owing to their high feeding, do not yield hair in either quantity or quality which renders its collection worth the cost. That yielded by lean animals is always the strongest and most elastic. Imported pig-hair is exceedingly dirty, and requires to be thoroughly washed and dyed before it can be used.

Both these kinds of hair are mixed with "soft" or mane hair from the horse, in proportions varying according to the quality of the product it is desired to obtain.

Sorting.—The manufacture of hair commences with the process of sorting. This is conducted in a room set apart for the purpose, called the sorting-room. The raw material, having been supplied to the workers, is first separated into long and short hair, the former being carefully reserved for the manufacture of hair seating, fishing-lines, brushes, &c., and the latter for curling. The sorting is next repeated for the purpose of separating the colours. White hair is esteemed the most valuable, being used for special purposes, and the supply being small. A third time this process takes place, this last being for its assortment into qualities. This is very important, and requires nice discrimination and sensitiveness of touch in the sorter, in order to perform the process efficiently.

Washing and Dyeing.—Each quality is next subjected to thorough washing in cold water, to remove dirt, dust, &c. It is then sent to the dye-room, and immersed for several hours in a dye bath chiefly composed of a decoction of logwood. When removed, it is of a dull-black colour. Further washing and cleansing then take place, the hair being put into large vats containing agitators, through which flows a stream of hot water. This treatment removes the superfluous dye, and further purifies the hair. After removal from the vats, it is passed through powerful wringing-machines, to express the moisture, and spread over the floor of an open room until perfectly dry.

Both classes of hair, long and short, undergo the above processes; but at this point, the treatment of the two sorts diverges into separate channels.

SHORT HAIR. *Mixing.*—Following the short hair, the next process is "mixing"—making a blend of certain proportions of horse-, cow-, and pig-hair, according to the quality of the article intended to be produced. Of these there are many, and the prices range proportionately from 6*d.* to 2*s.* a lb. When the blends have been properly laid down, the material is passed through a series of "willows," by which the different sorts are thoroughly incorporated, becoming homogeneous as far as mechanical admixture can produce such a state. After passing through the third of these machines, it is beaten and screened, to clear away the dust created by this treatment, and is then ready for the curling process.

Curling.—"Curling" is carried on in a separate room, called the curling-room. The curlers spin the hair into ropes or strands, by the aid of a machine similar to that employed in rope-spinning. The rope is further twisted in a second operation, by which means it is reduced to half its first length. By a third process, it is twined until it assumes a convolute form, when it is secured as a coil. These processes give to the hair its peculiar curl, which fits it for the purpose to which it is applied—"stuffing" for the seats of chairs, sofas, &c. But were it, at this stage, to be untwisted and used, the curl would soon be lost. It requires to be "fixed" in this condition, which is accomplished by the following treatment. The coils are immersed in cold water, and allowed to stand for several hours. On removal from this, they are placed in specially constructed ovens, which are heated to a very high temperature. After subjection to this heat for a sufficient time, the "curl" is permanently fixed; and the germs of all parasitic life are destroyed.

When the process of "baking" is finished, the hair has become a marketable article, and is sold either in the form of "hard curl," as removed from the ovens; as "soft curl," in which it is partially untwisted; or "towsed," in which the filaments are separated ready for use.

The comparatively high price of hair, whether of the horse, ox, or hog, has led to the search for cheaper substitutes. Of these, two have been utilized to a considerable extent, namely "Mexican fibre," which is very similar in appearance to hair; and "vegetable horse-hair," a product of Algeria, and known as *crin végétal* (see Fibrous Substances — *Chamærops humilis; Nidularium karatas*). The importation of the latter article has become considerable during the past 20 years, as it is extensively used in stuffing the lower qualities of furniture, either alone or in conjunction with hair. It is prepared and dyed in the localities of production, and is imported into this country in the form of hair ropes, to which it bears likeness. Neither of these articles, however, possess a tithe of the durability of real hair, and would not call for notice in this place were it not that they are made to simulate the latter.

LONG HAIR.—The long hair is applied to the manufacture of brushes and fishing-lines, but chiefly to that of hair cloth for upholstery purposes.

Hackling and Drawing.—After having been thoroughly cleansed, as stated before, it is combed by drawing the bunches through fixed combs, like flax-hackles, which work is done by boys. It is next drawn into different lengths and thicknesses, which is an important and tedious operation, requiring both delicacy of touch and quickness of eye. These lengths range from 14 in. to 35 in. This work is performed by hand, though attempts have recently been made to accomplish the drawing automatically. Black hair is subjected to further treatment, in order to obtain a full glossy blackness. White is bleached, in order to diminish the yellowish tint which is its natural hue; but this is never perfectly removed. English hair affords the best white, that obtained from foreign sources never yielding as clear a colour. It is also variously dyed by makers of coloured damask seating.

The best white hair is generally used for the manufacture of toilet-brushes, and fancy articles of similar classes, in which transparency constitutes an element of quality. Inferior whites are utilized in the production of paint-brushes, fishing-lines, &c., colour being then of minor import.

Hair Cloth.—The most important purpose to which horse-hair has been adapted is the manufacture of hair seating. A century ago, its qualities were highly esteemed in this application; but the invention of the Jacquard machine, and its application to the production of upholstery textiles, such as damasks, brocades, tapestries, &c., has caused hair cloth to be relegated to humbler classes of furniture than of old. Its cleanliness, durability, and coolness will, however, always ensure its retention as an upholstery fabric in warm climates.

By far the largest proportion of hair cloth is black, but it is sometimes made in colours, brocaded and figured, by means of a simple form of Jacquard apparatus, mounted on a hand-loom. This class of goods is a specialty of E. Webb and Sons, Worcester, who have also recently introduced a novelty in horse-hair fabrics, called the "Worcester carpet," made similarly to a "Brussels," but having the pile-warp composed of horse-hair. As may be inferred from the nature of the material, it is very durable.

In hair cloth, the warp is necessarily formed of a different fibre, most generally strong cotton or linen yarns. These are dyed and polished. The length of the hair decides the width of the cloth, as there can only be one hair to a pick. To knot the hair, in order to obtain a greater width, would seriously depreciate the quality, if not render it altogether unmerchantable.

Until within the past 20 years, this fabric was everywhere manufactured on the hand-loom, requiring a "server" to pick out the hairs singly from a lock, and hold one end, whilst the other was drawn across the warp by the hook of the weaver. This loom is still occasionally used, but has been generally superseded by a plan which dispenses with a server, the weaver working both baton and hook by means of a treadle, and supplying the hair for weft from her own hands. The "one-armed" loom, worked by means of a crank handle, or a long foot-lever, has come into extensive use in cottages, and in factories in which steam power has not been introduced.

To the ingenuity of the Americans we are indebted for an invention by which the above primitive process was first superseded. The chief difficulty arose from the nature of the material. The filling or weft employed not forming a continuous thread, an arrangement was required capable of picking up and laying in the warp shed each single hair as required, and to accomplish this with certainty and regularity. The wire motion of the carpet-loom undoubtedly suggested one method of overcoming a part of the difficulty. But this was not all that was needed. The arm or rod analogous to the looping-wire of the carpet-loom was made so as to operate like a finger and thumb, to grasp the hair when presented to it, but it possessed no power of taking up single hairs. Further mechanism was needed to secure this object, and many years passed before it was perfected.

In the Pawtucket loom, the work of picking up and presenting each separate hair to the receiving-rod is performed by a piece of mechanism at the side, containing a pair of nippers, called a "picker," one jaw of which has a groove or slit, almost invisible to the naked eye. This picker dips into a bunch of hair, and seizing one by the end, draws it up out of the bunch, and presents it to the before-mentioned rod, by the fingers of which it is carried transversely between the threads of the open warp. The motion of the picker is arrested until the hair has been laid between the warp, when it is again set free, and descends for another hair. A clever arrangement also provides that should the picker fail to seize a hair at the first dip, it can make a second or third before the receiving-rod comes for the hair.

In the factory of the Pawtucket Hair Cloth Co., where this invention was perfected and applied, a young girl is able to superintend 10 looms, thus performing the work of 20 persons when engaged upon the old hand-looms. The Pawtucket loom has been brought into extensive use, both in this country and on the Continent, for weaving hair cloth.

There are two other forms of power-loom, which are considerably easier to work, being simpler in construction. The least complicated is Henderson's. In this loom, the picker is attached to the end of the rod which draws the hair through the warp, and thus dispenses with the separate picking-apparatus of the Pawtucket loom. The arrangement for raising the warp threads is also much simpler, and less liable to get out of order; and another very important improvement is that the thick and thin ends of the hair are presented to the picker alternately. One end of a hair being very much thicker than the other, it is obvious that, if it were all laid in the warp the same way, one edge of the cloth would appear much stouter than the other; to obviate this, the hair for use is put into two holders, one presenting the thick ends to the picker, and the other the thin ends. An arrangement is made by which these holders oscillate, and so come alternately opposite the picker. In the Pawtucket loom, the hair is mixed, and the picker takes up thick or thin hairs at hazard, which destroys the beauty of the surface by making it appear streaky. In addition, it may be mentioned that a loom for weaving hair has been patented by Samuel Laycock and Sons, Sheffield, in which is incorporated Lyall's positive motion principle. In this loom, the hairs are taken from each side alternately. It seems, however, still to present a few practical difficulties.

The texture of hair cloths, with the exception of the fancy fabrics previously referred to, is chiefly that of a satinette armure or weave, by which the warp is quite hidden from view, only the bright glossy hair being perceptible to the sight or touch.

(See Hair; Woollen Manufactures—Worsted.) R. M.

HATS (Fr., *Chapeaux;* Ger., *Hüte*).

The feature which distinguishes the "hat" from other forms of head-dress is the possession of a brim. Hats are principally of two kinds—felt, and silk; these will receive separate description.

Felt Hats.—The production of felt must have taken place in the earliest times, the combined action of friction and moisture upon wool, and most kinds of fur and hair, being sufficient to form a felt. Such fabrics for clothing purposes long preceded woven goods. Felt hats for both sexes have been known in England for nearly 400 years. At the commencement of the present century, the trade was located in Lancashire, Cheshire, Warwickshire, and London. The stringent rules of the Hat-makers' Association had the effect of keeping the trade in a very few hands, and the exclusive use of manual labour rendered the production so small as not to suffice even for home needs. The more recent application of machinery to almost every branch of the manufacture has permitted a singularly rapid development, and the felt hat trade must now rank among the principal industries of the country.

Manufacture.—The basis of the "common" and "medium" kinds of hat is wool. It is important to select a sound and clean wool, whether washed or unwashed; dirty and broken wools must be avoided at any price, as being certain to produce bad results. Superior effects are produced from a mixture of several kinds of wool. Those preferred are "blue Cape," "Port Philip," and "Sydney" lamb, and such as are of medium staple, and capable of affording a soft and close fabric. These wools, unwashed, are carefully mixed, in proportions varying according to the particular product desired.

Opening.—The mixing having been completed, the wool is passed into the "opener," shown in Fig. 805. This machine performs the office of scavenger, opening the fibre of the wool, ejecting all loose sand and dirt, and preparing it for the "washer." At the bottom of the cylinder B, is a grid, through which the teeth in the cylinder play; within the cover A, shown raised in the illustration, other teeth are firmly fixed, through which the teeth of the cylinder pass, drawing the wool through the fixed teeth at the top, and acting the part of a rude comb. Care should be taken not to choke the machine with too much wool in feeding, and not to put the arms in too far. Having placed the wool in the machine, the workman lowers the lid A, until it covers the aperture down to C, and allows time for the wool to be passed through the teeth of the machine. Then, without stopping it, he gathers the wool in his arms, and places it in a large basket. Such a quantity is passed through as will serve for one operation of the washing-machine, described in detail in the article on Wool.

Washing.—Single and double machines are in use, according to the consumption of the manufacturer. If the single one with three rakes and lift be used, it will require the pan to be charged with soap and scour (caustic soda). These articles ought to be in a state of solution in two separate vats, the usual proportions being 1½ lb. of soap, and the same quantity of scour, to every gallon of hot water. Much will depend upon the state of the wool: if very dirty, more soap and caustic soda will be required to effect a thorough cleansing of the fibre. A little experience will soon determine the most effectual method of washing. The water must not be boiling in the machine, or the staple of the wool will be made knotty and harsh, giving much trouble in the after process. A thin layer of wool is placed upon the travelling brat in front of the machine, and introduced in exact proportion to what the squeezing-rollers will take with ease, all the wool having previously passed through the hot water and scour. The bowl of the machine ought to be cleaned out, the wool that is left behind being taken out of the dirt, and sent through the machine with the next mixing. The washed wool is passed again through a warm bath with a little soap, and will then be ready for carding. There is great economy, where the consumption is large, in providing a double machine; the first part will contain the strong scouring-liquor, and the wool, having passed through the first set of squeezers, continues to be washed in the second bowl, and finally passes out ready in one operation to the carding-engines, after having undergone a little drying.

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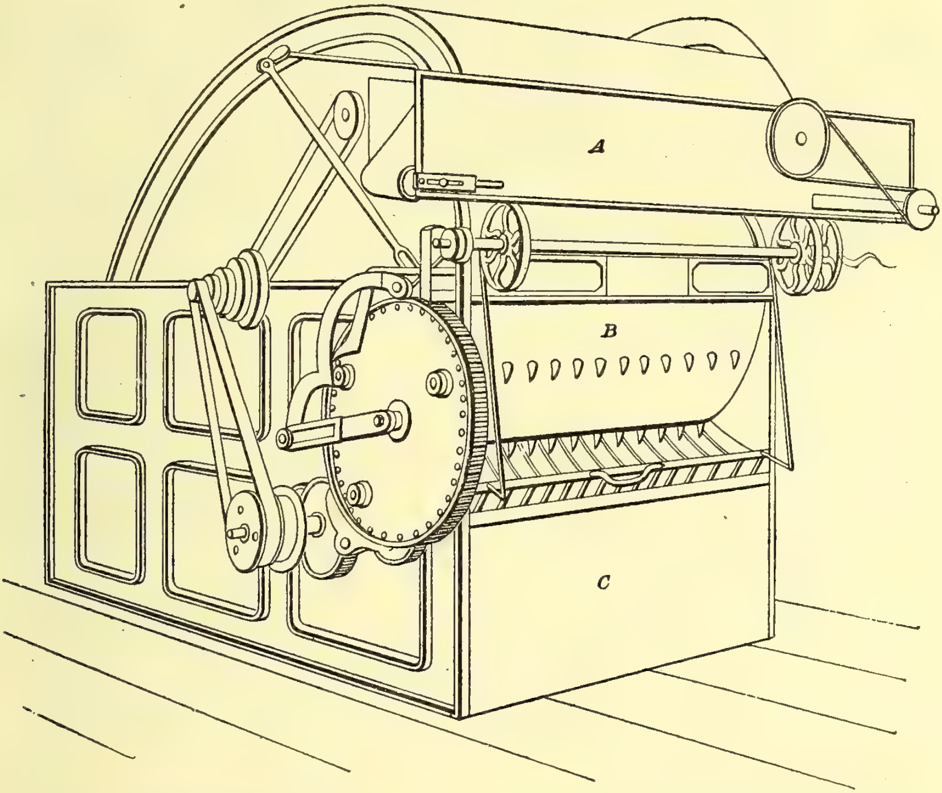

Carding.—The wool brought from the wash, and dried until containing only very little moisture, is taken to a small "opener," like the one used in the first process before washing. This fully prepares it for carding. Small manufacturers use single carding-engines for breaking up the wool first, and then take it through a second engine, before which the hat-former is placed, and where the form is completed. Large manufacturers find it more economical to use double machines, so as to complete the hat-forming in one process, the machine being placed at the end of the double engine. In Fig. 806, A is a travelling "brat," for taking the wool on to the first roller B, called the "licker-in"; this, on the breaking-engine, carries the wool in across the whole width of the machine. This first roller B, running at a high velocity, is covered with small stout wire teeth, which throw the wool on to the large central cylinder C. As a rule, this is made of iron, cast in one piece, turned very true, and where the casting has been drawn from the moulder's sand, strips of iron are bolted to the thin side, to make up the difference in weight between it and the thick one, thus preserving a perfect balance; otherwise, the high speed at which the cylinder runs is a cause of expansion, and produces such an irregular motion as to endanger the machine. It is therefore most important that all carding-cylinders should be exactly balanced, to run with the greatest smoothness.

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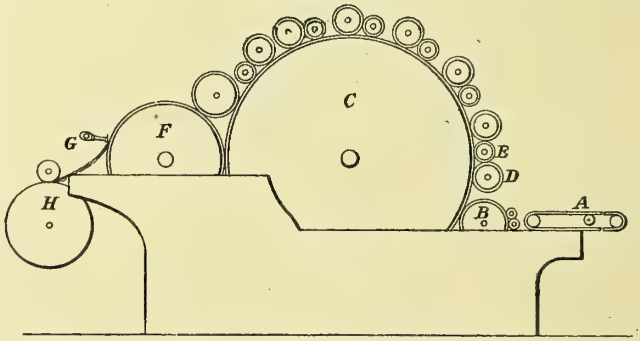

The cylinder C is clothed with small wire teeth, set in rubber strips, about 2 in. wide, the first cut in a slanting direction to a very fine point, and all nailed on with small tinned-tacks, driven into wooden pegs that are inserted in holes drilled in the cylinder for the purpose. After all has been covered, the card teeth are ground true and sharp by an emery wheel, driven from fixings on the side, and adjusted until it bears upon the teeth. The grinding is done by driving the cylinder C in a reverse direction. All the other rollers are covered with teeth in the same manner; but separate machines are used for the purpose. A central emery wheel carries one card roller on each side. As there is an independent feed motion at each end of a grinding-frame, the wire can be ground to a dead face and sharp. Setting these rollers on the card requires the utmost care, to prevent the wire from catching, or coming into direct contact with the cylinder or the other rollers. All being square, and ground up true on the face of the wire, the wool is thrown by the large cylinder C to the first roller D. The small roller E, called a "clearer," is driven by a small strap from the larger roller D, and almost in contact with it, and by its much higher velocity clears the wool from D. The wool is taken from E by the next roller, cleared by the corresponding one, and so on throughout the series, being lastly placed upon the "doffer" F. In front of F, is fixed a comb G, running at a high speed, and stripping the wool from the doffer as fine as a gossamer web.

Forming.—A hat forming-machine, Fig. 807, is placed in front of this doffer, at right angles to the position it occupies in the illustration, and the wool is so adjusted at the back of the card by two wooden guides, as to bring a web about 12–14 in. wide for the use of the "former." A very steady feed is requisite to make a good even form, free from the knots produced by bad carding. The person tending the machine takes the wool as it comes from the engine, guiding it with the hand to the cone marked C. This cone is made of tin or wood, of the most convenient size for the hat to be made, allowing about 5–7 in. greater length or width than the hat is wanted to possess in the finished state. Note well in making cones that the ends are never too sharply tapered, because the hood in every subsequent process of making requires to be opened at this point, and a sharp taper prevents the blocker from "unbuttoning" the tip in a proper manner, frequently spoiling more finished work than any other cause. The cone, being independent of the machine, may be of any required size. It is laid upon A, which are four tapered rollers, driven by bevel-wheels beneath; its weight, resting upon the revolving rollers, induces an opposite revolution in the cone itself. Adjustable screws enable the rollers to be raised or lowered, to fit the various sizes of cones. A foot-lever at B takes the wheels out of gear, by which the wool is made to run straight

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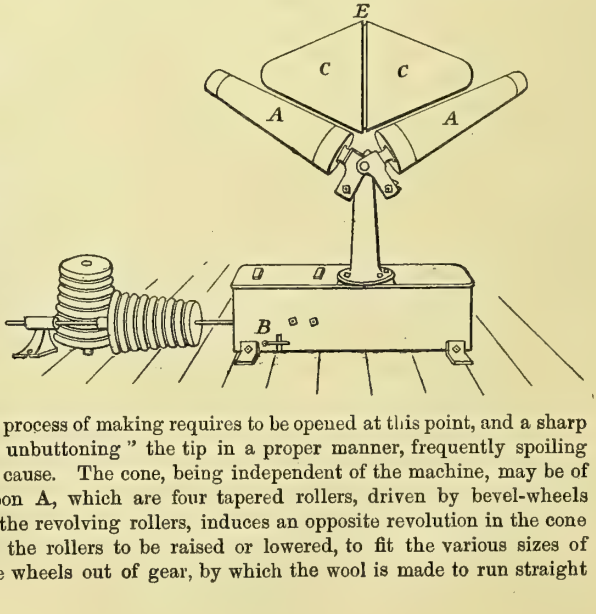
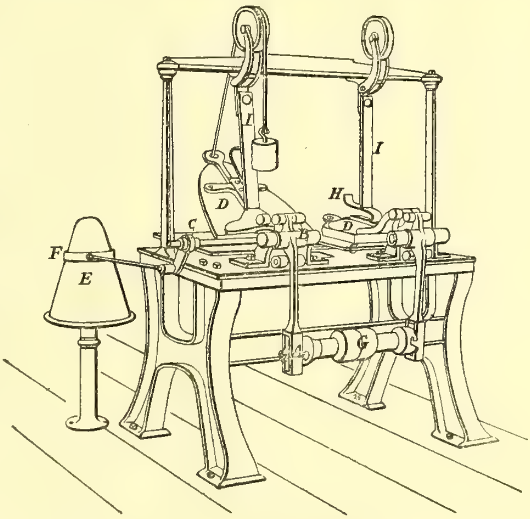


upon the centre of the cone C. When the machine is in gear, the rollers have a right and left radiating motion, revolving at the same time. Taking the wool or "sliver" from the engine with the hand, the operator passes it over the cone C; the machine making this peculiar motion, performs the lapping upon the two ends of the cone alternately, after the manner of winding a cord upon a stick. While guiding the wool as it passes over the ends of the cone, care should be taken not to allow the web to double itself, as this will make bad work. A little experience will indicate how many turns to take before lifting the machine out of gear, when, the wool running straight, the ends of the cone C are left without web, and it is run into the centre, according to the strength of brim required for the hat, after which, the machine is placed in gear again, and sufficient laps are added to make up the weight of hat wanted. A pair of shears are slipped through the web into the groove E, about ½ in. deep, which serves to guide the cutting straight; when cut through, each hood is taken off, weighed exactly, and pared at the edges if too heavy.

To make "hard" hats, the brims are formed very thick, with a very thin "tip," as the crown is called. "Soft" hat forms are wound on about even in thickness. The same is the case with "framed" hats. "Soft tops" are formed very thick, as the crown, when finished, must feel thick and soft, and the brim hard.

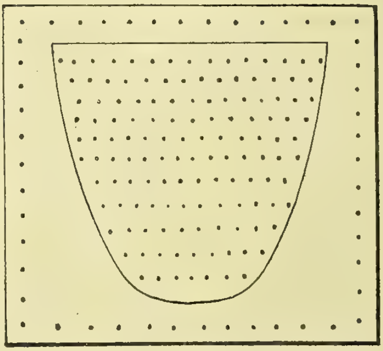
808.



Hardening.—The formed hat is next taken to the "hardening"-machine, Fig. 808. A place should be selected for a table with good light in front, to enable the workman to look inside the wool forms against the light. That will at once show all the thin places, which are made good by putting thin layers of wool over them, to make up the felt to an even thickness. As the hardening-machine runs with great velocity, and by the motions of the various parts produces a considerable vibration, heavy stone foundations are necessary to secure steadiness, which is absolutely essential to good work. Of the pair of pulleys G for driving the machine, one is fast, and the other loose. On the end of the shaft, is fixed a solid face-plate, furnished with a groove, in which a T-bolt can be raised in a slot. This increases the diameter of the circle as the shaft revolves, communicating a right and left motion to the lever A, for the bolt, having a square collar planed to fit the aperture in this lever A, acts as a slide-bar, giving about 1 in. of travel in each direction. As the lever A is fixed by a key at the point B, the motion diminishes upwards. Above B, is seen a fixing, also keyed to the same shaft B. This fixing is about 7 in. long, bored at each end, and linked together by two pins, one end being attached to the top cover D, the other fastened to the bottom chest C, thus producing a slight shivering motion, similar to the effect of placing one hand on the other and moving them about ⅜ in. at a great speed. If the travel is too long, the tendency is to corrugate, or "fridge," the hat form. Should this take place, nothing will remove it, and the damage will be clearly seen after the hat is dyed and finished. Other causes producing the same result are (1) having the face of the top lid D too level, (2) an excess of pressure produced by the lever I, when brought down upon the spring A. C forms the bottom cover, travelling in four grooves. The bottom is a steam-chest, perforated on the top side with small holes, as seen in Fig. 809. The portion having the rude form of a hood is raised a little, planed true, and covered with a stout linen cloth, in several folds if thin. The cloth is strained after nailing one end, and is drawn from each side until, when wetted, it becomes as tight as a drum-head. The holes on the outer edge are filled with wooden plugs, into which are driven the nails for holding on the linen cover. Should too great pressure of steam be used, the fibre will be damaged, leaving upon the hat the marks of each hole in this bottom chest. This may be avoided by regulating the steam, or the length of travel of the cover, or the pressure. Some experience will be required to secure the best result. If the marks of "fridging" are not seen on the inner side, nor the damage by steam or other causes, the imperfection will be got rid of by turning the hat inside out when sending it to the next process. Taking a number of forms to the table, the workman, after carefully stopping up any thin places, cuts a piece of linen cloth of the same shape as the inside of the hat form, steeps it in water, wrings it, and by inserting it between the folds, prevents the hood felting fast together. Placing the hood under the cover D, he brings down the lid as seen at work in H, the lever I acting as a pressure-bar on the spring H. So soon as the steam and pressure settle the wool, the hood is hardened and opened out, the linen cloth is removed, the hood is carefully looked at again, and any defective places are repaired; it is then folded so as to bring into the middle the two sides or edges that received no pressure, and is again placed in the machine. When removed this time, if the process has been carefully conducted, the sides all round will have been transformed from a thick flossy wool to a loose thin cloth. The crown or tip has been first solidified. To effect this in the same manner as the sides, a stout iron pillar, terminating in the cone E, is used. By attaching a side bar from the shaft of the machine, the same motion is given to F. This ring must be made into a pad, covered with linen. The hat form is placed over the cone E, which is perforated, to allow of the escape of the steam admitted to the inside. The workman lifts the rod F, places it with this linen covering upon the top of the hat resting on the cone, and turns on the steam; the top becomes hardened by the mere weight of the side bar. The form is thus completely hardened and ready for the next process.

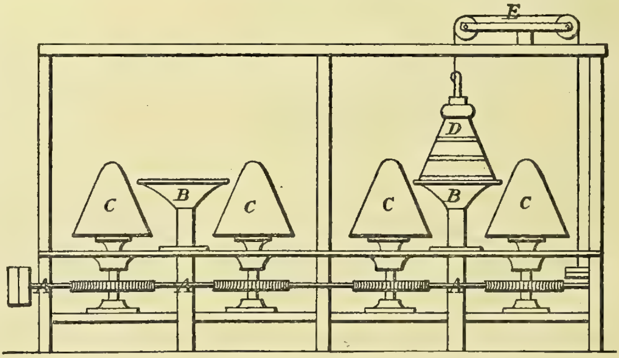
This machine, known as the "No. 1 hardener," is perhaps the least complicated, and certainly the most approved by all manufacturers for a large production with little labour. It is suitable for all medium wool hats. For the purpose of hardening fine wool and fur hats, recourse is had to the "No. 2" machine, known also as the "cup and cone hardener." With the low class and medium wools, the staple is not so easily thrown out of shape, nor injuriously affected by pressure and steam, as the finer sorts. Therefore the No. 1 hardener should be used by all persons engaged in the common and medium trade. Fine wool under pressure in the No. 1 machine would flatten out too large, so much so that a large quantity of work would be spoiled, for it could never be felted down to the requisite size to make good work. The aim of the manufacturer using the finer material is to confine the hood, to prevent its expanding too much. If he can once concentrate it by hardening the felt to a proper size, his object is easily gained. The No. 2 hardener, Fig. 810, effects this completely, and is the best machine for this class of work.

809.



In making fine wool hats, the same processes of carding, &c., are to be followed, the workmen acting precisely as with the No. 1 machine, so far as regards the hardening of the bodies and making them sound. The difference in working will easily be understood on reference to Fig. 810. A is a driving-shaft, revolving the upright spindles surmounted by the cones C. These last are covered by linen cloths. B is a table for supporting the cover D, into which steam is injected for hardening the body, and gives the workmen easy access for removing the form. Setting the cone C in motion the hood is placed over it; when evenly placed, the cover D is pressed upon the hood, confining it on all sides. The chain that passes over the lever E keeps constantly lifting the top cover with a spring, the under cone revolving; thus the wool is settled down, and hardened evenly on all sides simultaneously, the tips included. No portion of the wool escapes pressure, it being confined on all sides at once. The machine is peculiarly fitted for all finer materials, and is absolutely necessary for the class of work just described. The hoods thus hardened go into the next department, which will be described presently. It will be convenient first to describe the process of forming the finest fur hoods, ready for the hardening-machine, in order that all qualities may be taken together into the "planking-room."

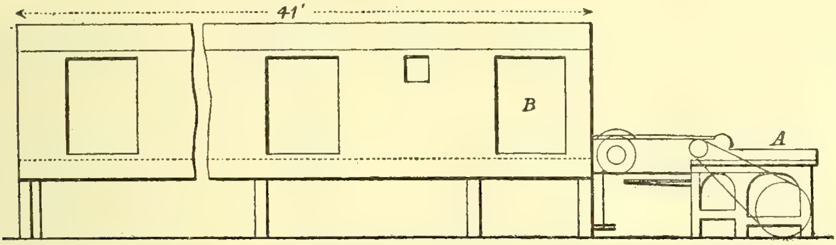
810.



Furs for Hatting.—Fur for hat-making purposes must be most carefully prepared and sorted. The furs principally used at present in the manufacture of fine goods are coney or hare, and rabbit, the best qualities coming from northern countries (see Fur). The first process the fur undergoes is "carroting," which consists in applying to it a solution of 32 parts mercury in 500 parts commercial aquafortis (nitric acid). The object of this is to render its felting easier, and to avoid the excessive use of acids in the subsequent operation of planking. Much experience will be required in selecting fur, to avoid that which is defective in quality, and to detect that which is rotten. This is a most difficult matter, and one of the best safeguards is to purchase from none but first-class firms. The skins are taken into a hot room to dry, are sorted into qualities known in commerce as "back," "belly," and "side," and are finally made up in bundles and sold by the lb., the price varying from about 5*s.* to 20*s.* It should be noted that hare-skins have a solution of arsenic applied to them before the fur is removed, to prepare it for felting. The choicest qualities of hat are produced from beaver-fur; commoner ones from otter and musk-rat. An excellent felt for hat-making purposes is made from the fur of a large species of water-rat, a native of S. America, and more than a million skins are annually exported from that continent for the purpose.

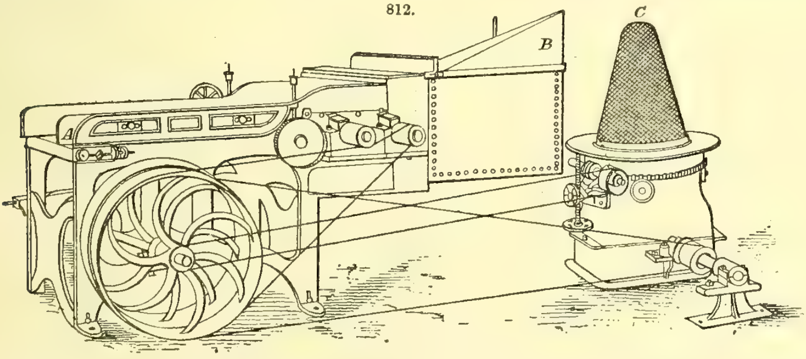
Fur-blowing.—After selecting the class of fur suitable for the manufacture of the goods desired, it is taken to a room adapted for the blowing-machine, Fig. 811, which separates the hairs from each other. This machine consists of three parts: an apparatus for bringing the hair, a conduit pipe, and a chamber or series of chambers. The hair is first conveyed on an endless belt of cloth A, provided with fans, and is blown into the first chamber B. This is furnished with a glass window, through which the fur can be seen kept in violent commotion by the wind from the fans. The finer hairs adhere together, and pass along from one chamber to another, the finest being carried farthest, while the coarse and unsuitable qualities fall into boxes at the bottom of the first chambers.

811.



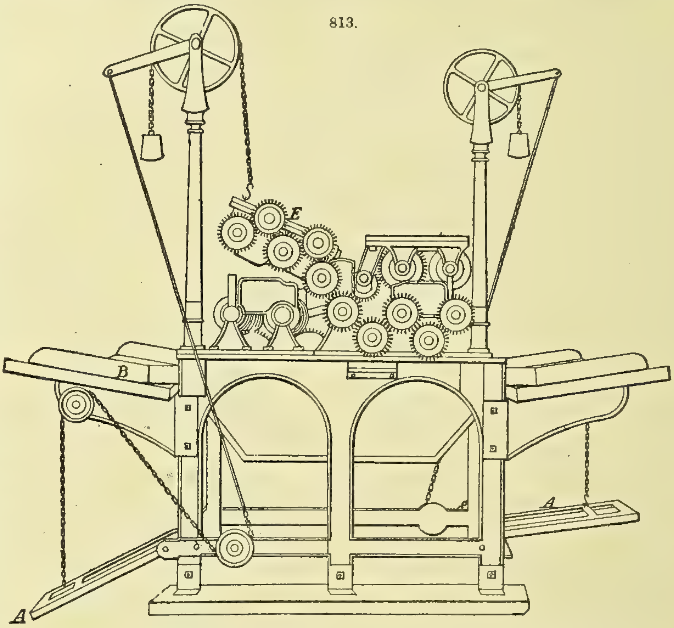
Fur-forming.—The fur-former, Fig. 812, is next brought into use. The "stock" or "blown hair," as it is termed, is weighed out in the exact quantities required to form one hat, and is placed upon a travelling "brat" or "apron" A, by which it is carried between two horizontal feeding-rollers, covered with felt, and is immediately seized by a cylinder, making about 3000 rev. a minute, and furnished with several longitudinal lines of stiff brushes. This generates a current of air, and scatters the stock, blowing it out through a vertical slot B, at the farther end of the machine. A thin stream of hairs is thus ejected against the cone C, which is made of copper, perforated with small holes, and revolves on a vertical axis. A strong current of air is produced by an exhaust-fan or air-pump, placed within the cone, thereby assisting the fur in attaching itself to the cone C. During the operation, the cone and its covering are kept constantly moistened with water. The revolution of the cone on its axis soon causes it to be uniformly covered with a fine felted fabric. The slot B can be regulated by means of a sliding-board, the manipulation of which enables the operator to direct the stream of hair to any desired part of the cone C. An extra quantity can be placed upon the brim if wanted, or the whole hat can be formed of even thickness; this is as much at the discretion of the operator as in the wool-former.

812.

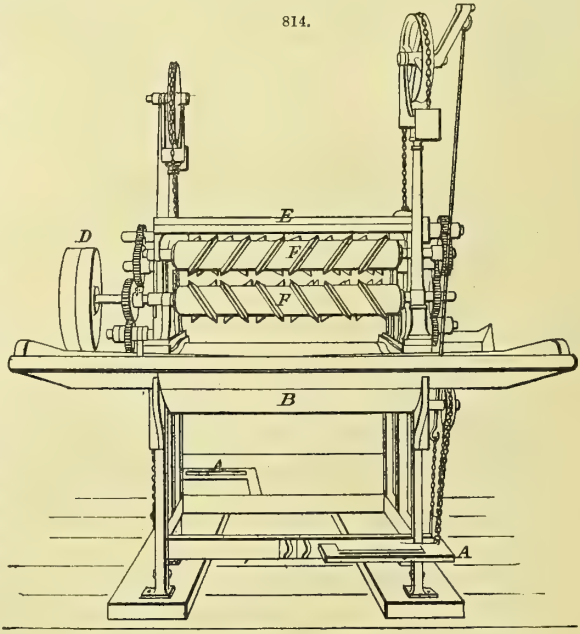


While the right hand of the workman is directing the stream of stock or hair, the left hand is applied to the felt to moisten it, and to ascertain its thickness and uniformity. When the whole weight is drawn upon the cone, the pneumatic action is stopped, and the felt is covered with a wet linen cloth, or a tightly fitting copper cone, similar to the one within the felt. Both are plunged into a bath of dilute sulphuric acid, and made sufficiently cohesive to be safely lifted from the mould. The felt requires to be hardened still more, or it would fly out of shape, and be spoiled. In some cases, workmen "run in" the felt, i. e. dip it into sulphuric acid and hot water, and roll it gently by hand until it is firm enough to be put upon the No. 2 cup and cone hardener, or is brought into such a state that it will not felt together. In all the processes, whether by hand or machine, cloth must be introduced into the hood, to prevent its fastening together. In all cases where a mixture of sulphuric acid and water is used, the strength is understood to be such as will afford a strong sour taste on the tongue, unless otherwise stated.

813.



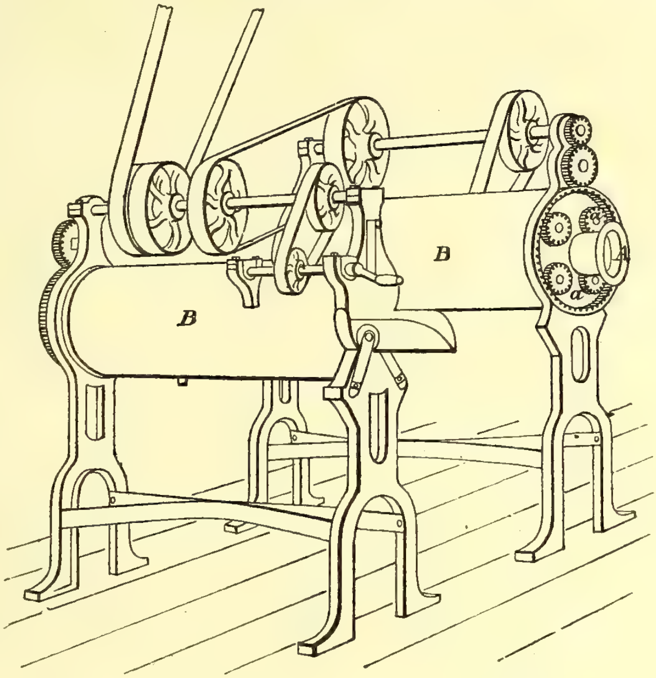
814.



Planking.—Having made the felt firm enough to stand the pressure of a machine, both fur bodies and wool bodies may be taken into the planking-shop, where are machines specially adapted to reduce them to about $\frac{1}{3}$ their original dimensions. The first machine is very suitable for wool bodies. Two views of this are shown in Figs. 813, 814. The foot-lever A, when depressed by the operator, raises the entire frame and gearing-wheels which drive the rollers F, attached to the frame E. The rings seen on these four rollers, two on the top frame and two on the bottom, are composed of vulcanized indiarubber, to resist the corrosive action of the acid used, and are placed in such an oblique position that the revolution of the opposite rollers causes them to attack the felt with a screw-like motion, producing an action like kneading with the hands. The operator takes 8–12 hats, and rolls them in an indiarubber cloth about 30 in. long, first dipping them into the lead-lined cistern B, which is charged with a mixture of hot water and sulphuric acid. Placing his foot upon the lever A, he raises the frame as seen in Fig. 813, and introduces the roll of hats between the top and bottom rings. The foot is taken off, and the weight of the frame E presses the hats down. After being worked in this machine for some time, the hats are removed from the cloth, opened out, and folded so as to bring the edges to the middle, when they are again run through the machine. These are supposed to be "all wool" hats. The operator piles them beside him, until he has a quantity sufficient to fill the fulling-stocks.

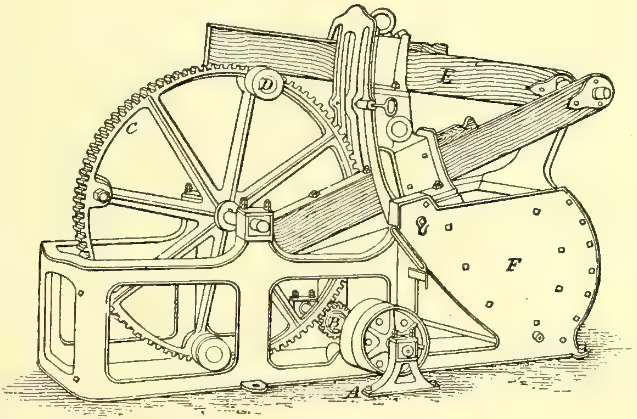
Twisting.—If the hats are fine ones, they are planked through in the "twisting"-machine, which is sometimes made double, as shown in Fig. 815. A roll of hats taken from the hardening process, if "wools," or if "furs," settled first by hand, are wrapped in a wet linen cloth, dipped into vitriol (sulphuric acid) and water, and pressed into the trumpet-mouth A. The passage diminishes in diameter as it traverses the length of the cylinder B, and is corrugated throughout. As the cylinder receives a rotary motion from an internal wheel driving the four small rollers *a*, the hats are twisted as they advance, and are compressed gradually smaller, until they are delivered at the other end; here they are placed in the mouth of the second cylinder, and return through it. The hats are next opened out, their edges are reversed as on the first machine, and they are completed by dipping in the acid and hot water bath, and working them through the machine until reduced to the required size.

815.



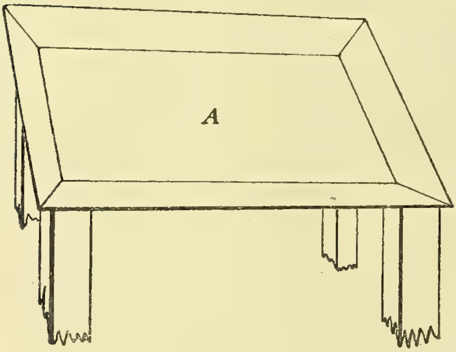
Fulling.—The woollen hats, described as being merely felted, so as not to adhere under pressure, are deposited to the number of 40, 50, or sometimes 60 doz. at a time, in the fulling-stocks, shown in Fig. 816. The driving-gear is at A; B is a small pinion, turning the large wheel C. In large stocks, four lugs are bolted at equal distances apart on this large wheel, as at D, for lifting the long lever E. The chest F has a circular form internally. The hats are doubled carelessly together and put into this chest, which is constantly fed with sulphuric acid and warm water. Here they remain until the beating action of the stocks has milled them up to the right size. A lead-lined cistern, fixed above the stocks, is very convenient for containing a supply of warm water and sulphuric acid; the liquor may be conducted to the chest by a leaden pipe, branching at the end into two, extending across the chest F, and finely perforated, so as to form a self-feeding arrangement. The felting being completed, the hats must be passed once more through the

816.



No. 1 planking-machine, to straighten them, and bring their edges evenly together. Besides these planking-machines, a "battery" (Fig. 817) is required, at which six men can work. In the centre A, is a lead-lined cistern, containing clean water, or acid and water, as required. The workmen have each a space allowed in front to work the hats upon. The battery can be used to plank hat-bodies complete to size, if the goods are fine; or to stretch the hats from the planking-machines. Each process being completed in this department, the goods are washed out in clean water, and afterwards passed between a pair of wringing-rollers, to get rid of the superfluous acid. Thus partially cleansed, they are gently dried in a stove fitted with racks on every side, as well as in the middle, leaving room between the narrow strips on each shelf for the heat to circulate over the entire surface of the hats.

817.



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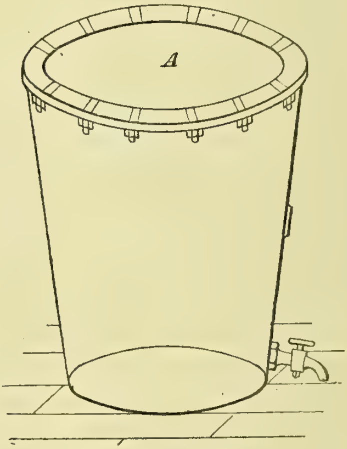
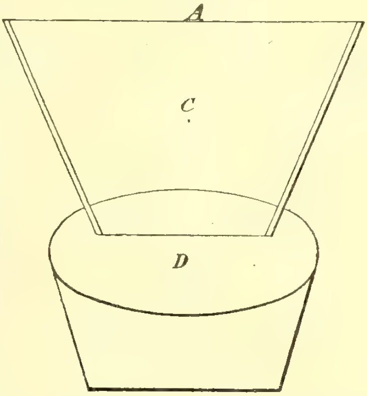


Stiffening.—Stoving finished, the hats are ready for "stiffening," a process requiring great study to produce good results. Each hood should be carefully examined, to discover any very thin ones that may have escaped notice. Should any be found extra light, additional stiffening will make up for it, if noticed in time; but quantities of goods are hopelessly spoiled through careless examination at this stage. The mixtures used for the stiffening process vary according to the taste and experience of the maker, and the class of work he happens to be engaged upon. The mixtures here given will be found perfectly safe, if worked as directed. A number of large tubs, and several dipping-vats will be required for the operation. The first apparatus used will be a steam-chest, Fig. 818, for reducing the "proof." This chest is double-jacketed, for the admission of steam to the interior. The inner part A fits into the outer, the joints being made good with iron-turnings and sal ammoniac, and the rim bolted on as shown. The tap at the bottom is useful for letting off condensed steam, accumulation of liquid in the jacket or steam-space preventing the contents of the pan from being brought to the boiling-point. The ground floor is the most suitable place for establishing this apparatus, as it often happens, through carelessness, that the proof or stiffening preparations boil over. Much water is also required in this department, causing inconvenience if it has to be carried up stairs. It is impossible to insist too strongly upon the great importance of thorough study of the art of proofing, as upon it most largely depends the success and reputation of the manufacturer. A perfect knowledge of the nature of the materials is indispensable, while special chemical knowledge will more than repay any student who directs his attention to it. The complete ignorance of the workmen upon whom may depend the success or destruction of perhaps 1000 doz. hats a week, renders it imperative upon the manufacturer to master the details of the process. It will suffice here to describe the important outlines, which, if followed, will at all events conduct to a satisfactory termination the proofing of the soft and hard felt hats that form the bulk of the general home and shipping trades.

The first to be considered is the mixing of what is known as a "water-proof," for the stiffening of the common and medium woollen hats, intended to be of a black colour. Steam is turned into the proof-pan. The workman then weighs out 8 lb. rosin of good quality, 6 lb. gum "thus" (naturally solidified turpentine), 3 lb. borax, and 1 lb. soda. The borax is first dissolved in warm water in the steam-pan, and the rosin, thus, and soda, are then added. When these are quite dissolved, 30 lb. shellac (good "garnet" or "button" will do) is added, and the whole is allowed to dissolve, being kept well stirred to prevent it adhering in lumps to the bottom of the pan. Special observation is needed to note the change in colour. A little experience will soon teach when to add warm water, which is done at first in small quantities, without relaxing the constant agitation of the compound. A gradual reduction is made in the temperature of the water poured in, until cold water is received by the shellac without chilling it. The strength required will enable the workman to judge of the thickness of the mixture, for water should be added until it is within a few degrees, by Twaddel's hydrometer, of the strength required to proof the brim of the hat, this being the strongest part. "Letting-down" the proof by water after this first process does much damage to it; the grains of shellac resisting combination with the water, only a partial agglomeration takes place. A microscopical examination of the mixture in the two states, the one just as it is let down in the steam-pan, and the other after being let down with water, will show that the latter, instead of being perfectly mixed with the body of shellac, is only partially held in solution. The fact that this second mixture may proof the brims and crowns of the hats to the right degree, as shown by the gauge, is not sufficient; the hats may be completely ruined nevertheless. The secret of this lies in the fact that what ought to have formed strength will have evaporated in the stove, leaving the damaged shellac incapable of performing its office. When completed, the workman can test whether the mixture is good, by rubbing it between his thumb and finger: if sound, it will slip between them like glass; whereas if broken by being chilled too quickly, the feeling will be gritty, and much like that of fine sand. A large, shallow vat must be provided before commencing the process. By placing across this a slab of wood, on which to fix a fine sieve, the proof can be emptied from the steam-pan, run through this sieve, and left until quite cold before using. As the wool bodies left in the stove are brought to the proofing-room, they should be allowed to cool thoroughly before being subjected to the proof. The "dip," reduced to the right gauge, is contained in a vessel shown in Fig. 819. Some hats require 60° Tw. in the brim, and 30° Tw. in the crown. To manipulate the hats rapidly, two stools of this description are indispensable. The operator, standing at A, dips the hat into the vessel D containing the proof, or "stiff," as it is frequently designated, sufficiently deep to include the entire brim. When finished, he lays the hat on the slab C, and draws off the superfluous stiffening by a strip of boxwood, about 1 in. thick at one end, and tapered down to a blunt edge on the other, and called a "draw-block," avoiding too heavy a pressure. On immersing the brim again, sufficient stiffening is imbibed, and the hats are taken into the stove, first reversing the folded edges. The draw-block removes any undue stiffening that may have been attached, and thus secures an even coating. The hat is then passed to the next stool, where the operator thrusts a short, stout stick into the inside of the hood, and plunges the hat bodily into the "crown" proof. Here it is saturated inside and out, giving a little time for it to absorb the preparation, after which it is withdrawn upon the stool, and all the superfluous stiffening is drawn off, as in the first process, and runs back into the dipping-pan. The hood is rubbed on all sides with the bare hand, to destroy any patches of thick proof that might have escaped notice. Opening the broad side of the hood, and holding it by the crown, it is laid on the floor to set hard. So soon as the operator has accumulated a dozen, he rapidly sets them in the steamer for 20 minutes, and afterwards in the hot stove, for 60 minutes, to sharply fix the proof, removing them into the air afterwards to cool. They are then again ready for the steaming-chest. Before proceeding to explain this process, it will be necessary to follow fine goods through the proofing department, as well as soft hats. In all dip proofs where the steam-pan is used, warm water can be employed to dissolve the borax, and this must always be the first process, before adding the gum thus and rosin. For a mixing of soft proof, weigh out 4 lb. borax, dissolved first in warm water, 3 lb. rosin, and 3 lb. gum thus; dissolving this, add 30 lb. shellac; keeping the mixture well stirred, 1 pint linseed oil will be mixed in, pouring in a little warm water first, and "breaking" the shellac gradually until cold water can be added. Having brought it to the required strength, it is poured into a vat, kept for the purpose, for a couple of days before using, as it works much better after standing. The strength, measured by hydrometer, must be left to the judgment of the maker, for the felt for this class of hat is made of so many strengths that, while some require scarcely any stiffness, others need 5-10° Tw. in the brim—less in the crown, as it is to be more pliant.

819.

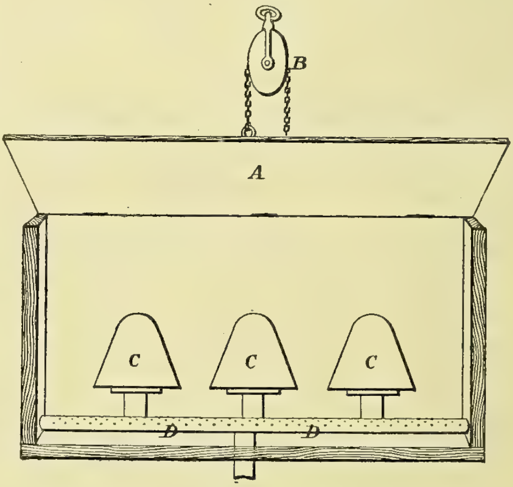


The mode of dipping is the same as for hard hats; less heat in stoving will suffice.

Spirit Proofing.—Some account must now be given of the most popular preparations, both English and American, for the proofing of fine goods, technically known as "spirit proofing." The stiffening of these goods, like that of all others, requires careful attention on the part of the maker, in order to ensure good results. The climate in which the hats are to be worn should influence the character of the proofing. The dampness of the English air demands a much harder stiffening than is requisite in America. In the largest manufactories in the latter country, where fine hat-making, both hard and soft, has reached a very high state of perfection, the most favoured preparation is 20 lb. of orange shellac, dissolved in the cold in 5 gal. spirit (methylated or alcohol), in a close vessel, with repeated and careful stirring, to keep it from "lumping," and sticking to the bottom. The vessel commonly used is in the form of a barrel or churn. When fully melted, the "stiff" is made ready for use by being thinned down by spirit. The strength is not gauged by hydrometer, but is judged by actual application by an experienced hand. A good stiff brush is used to put in the proof. Most strength is given to the brim, as in the first case.

Another American proof, of a cheaper kind, for soft hats, is made in the steam proof-pan, by dissolving 9 lb. shellac with 18 oz. carbonate of soda in 3 gal. water. The soda is first gradually introduced, and is soon dissolved; then the lac is put in, and stirred occasionally for about an hour, by which time it will be dissolved. The whole is then left for an hour or two, when it may be taken out and set to cool. It will be found better if allowed to stand for a few days after being made. When used, it is reduced by water, as explained in the first mixing of hard proof for woollen hats, the strength being 2°–10° Tw., according to the thickness of the felt. This mixture will be found very good for soft or semi-stiffened hats. It is the habit amongst some makers to add 3 oz. salt. The salt counteracts the soda, and the hats may be blocked immediately after being stiffened, thereby saving time, and dispensing with the use of the stove. The following mixture is esteemed by some English makers:—7 lb. orange shellac, 2 lb. gum sandarach, 4 oz. gum mastic, ½ lb. rosin, 1 pint solution of copal, and 1 gal. wood naphtha or methylated spirit. The lac, sandarach, mastic, and rosin are dissolved in the spirit, and the solution of copal is added last. This is rubbed into the body with a brush, like the former spirit proof for fine hats. The hats, both hard and soft, are placed in the stove at a temperature of about 82° (180° F.) if of wool; less heat will serve the purpose of spirit-proofed hats, and care must be taken lest they catch fire. Bringing the goods from the stove, a steamer is provided, which will hold two rows of pegs, on which to place them while undergoing the steaming process. This chest, Fig. 820, is composed of wood, about 2 in. thick at the sides and bottom, bolted at the sides with cross-bars to strengthen it. The figure shows the inside of the chest with the lid open. A strong fastening must be attached to the lid, to prevent its being lifted by the pressure of the steam, while the hats are undergoing the process, which lasts for 20–30 minutes.

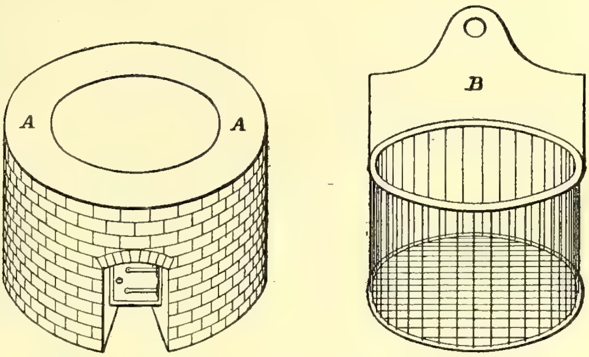
820.



The lid A is raised by a chain attached to a pulley B, secured in a stout pillar, and enabling the operator to adjust the lid to any height by means of a balance-weight attached at the other end; C is a row of wooden pegs, on which to hang a pile of hats, say 6, 8, or 10, as required; D is one of a series of perforated pipes for injecting the steam evenly throughout the chest. Placing hats on these various pegs, the lid is brought down and securely fastened, and steam is turned on for 20 minutes. On opening the chest, the hats are taken by the taper end, and dropped singly upon the floor to set until perfectly cool. When a sufficient number is accumulated to fill the hot-stove, the goods (if for hard hats) are passed into this stove, and kept at a temperature of 82° (180° F.) for 6 hours, allowing the heat to gradually decrease from that time. In the steaming process, the stiffening is cleaned from both the outer and inner surface, by the equal pressure of the steam on both sides. It needs careful attention to avoid scorching the fibre, as this will destroy the peculiar gelatine inherent in the hair of animals, and which accounts for the fine softness of the finished article; if once extracted, the latter is left wiry and harsh. This completely spoils its character, and will explain a fact hitherto not generally accounted for, that the dry, harsh sensation is the result of this extraction of gelatine. In dyeing, the same care should be taken not to destroy it by boiling. After a thorough stoving, performed in a special apartment if possible, on account of the dangerous character of the work, all the goods are removed to the dye-house, where a number of copper pans are fixed for the reception of the hats, no other material so well withstanding the corrosive action of the acid accumulated in the hats.

Dyeing.—As the largest proportion of the hats are to be black, preparations are made to dye what is required daily for the various departments. Some makers prefer pans wholly heated by fire, asserting that the liquor is not damaged, weakened, nor affected in its nature the same as in those raised by steam. Others conduct the black dyeing in a large pan heated both by a steam-coil of copper pipe and by fire. If possible, a large room on the ground floor, with a good north light, will be very advantageous, and ample room must be provided for opening-out the hats singly, as this assists most materially in striking the colour very deep. For a large pan, a cage, as shown at B (Fig. 821), is made to fit inside the pan A, and a windlass is attached to lift the entire "dye" or batch of hats at once. This will save much time and labour. The dyeing of hats is much more difficult to perfect than the dyeing of ordinary wool for wearing and other purposes, where the surface of the fibre sustains no damage. In the former case, the dye must saturate the fibre intimately, or the colour will look very grey and dingy. The subsequent process of "sand-papering" seriously affects the surface, and requires the presence of nothing but free wool, dyed thoroughly through each fibre, or an even colour will be impossible. The dye-pan A (Fig. 821), is of stout copper, built into brickwork, and allowing room around the edge for the workmen to walk and agitate the hats in the process of dyeing. The cage B is also made of copper, to prevent active corrosion. The workman prepares the pan first for a batch, say 50 doz. of woollen hats, by extracting 90 lb. logwood in a warm bath; the liquor is well stirred, and the goods are then immersed. The heat of the pan must not exceed 82° (180° F.): boiling would cause harshness in either fur or wool, as previously explained, by extracting the gelatine. The goods are thoroughly turned, while the pan is kept at a regular heat. After 1 hour, they are removed, and each hat is spread out carefully to expose it to the atmosphere, this deepening the colour. They are then again placed in the dye-pan, and the process is continued for another hour. Previous to this second immersion, 15 lb. copperas and 3 lb. verdigris are added. After constant turning over during the second hour, the hats are taken out and laid singly on the floor, as before, remaining for about 20 minutes. A third immersion will complete the dyeing in a satisfactory manner, if due care has been taken. Many dyers allow the hats to remain for only 40 minutes in the pan; in fact, the shorter the time that the hats stand in dye, with due regard to colour, the better they will go through the final processes. A much favoured dye for common hats is to mordant them first in a weak bichromate of potash bath, separate from the dye-pan, and then to place them in the liquor. The use of copperas can be largely avoided by this process; but some object to it, on the ground that the bichromate makes the wool hard and harsh. Yet many makers are able to bring back the softness, and commend the process.

821.



The following is a capital dye for fine hats, producing a good bright black, the quantities named being for dyeing 100 hats at one operation. Into a copper containing 55 gal. boiling water, put 9 lb. best liquid extract of logwood at 30 degrees, 4½ lb. crushed cashew bark, 4½ lb. sandal wood in powder, and 2¼ lb. soda crystals. Enclose the whole in a linen bag or wicker basket, so that they do not settle at the bottom of the copper. When the ingredients are dissolved, put the hats in, and allow them to boil gently for 2 hours. Then take them out and let them get quite cold. Now add to the bath, 3½ oz. chromate of potash and 9 oz. sulphate of copper, and cool the bath by the addition of several pailfuls of water. Return the hats to the bath, and allow them to simmer for an hour. Again take them out, and let them get cold. After adding 2½ lb. sulphate of iron, put the hats in again, and let them boil gently for an hour. Should they have a red appearance, add to the bath another 2½ lb. soda crystals. After these operations, the hats must be piled up, and covered with a thick cloth for a day; then subject them to a vigorous washing, and eliminate the copper, using hydrochloric (muriatic) rather than sulphuric acid, as the latter always draws out the dye. When the copper is thus removed, pass the hats into cold water, in order to free them from acid. For the final operation, prepare a bath of Panama wood, just simmering, and place the hats in this for ½ hour. This bath sets the colour, and gives brightness to the felt. Upon taking them out, if soft hats, the water must be drained out of them by pressure. To produce a violet-black, the cashew must be replaced by the same weight of orchil. A blue-black is obtained by leaving out the catechu and sandal wood, and replacing them by 4½ lb. of orchil. For burnishing, the sulphate is replaced by 1 lb. 2 oz. sulphate of copper. If a greenish-black or dark-bronze tint is desired, the sandal wood must be replaced by 4½ lb. liquid extract of Cuba yellow wood at 30 degrees.

An American dye for best fine hats (12 doz.) is composed of 144 lb. logwood chips, or its equivalent in extract, 12 lb. green sulphate of iron (copperas), 7½ lb. French verdigris, placed in a boiler, and heated to 88° (190° F.). During the operation, the hats are kept turned; when removed from the pan, they are exposed to the action of the air. When the manufacture is extensive, two boilers will save much time, one batch of hats being in the pan while the other lies exposed to deepen in colour. From 6 to 12 hours are required to complete the operation. The copperas and verdigris are added for the second bath.

An English composition (for 36 doz. "medium furs"), mordanting first with the bichromate of potash, is 120 lb. of logwood chips, or the equivalent of extract, 4 lb. verdigris, 12 lb. copperas. The process is conducted as before. To dye soft goods, more logwood will be required, as the hats absorb more; and it should be noted to give more for extra weight of material in all cases, and that the strength of the liquor be kept up, or bad dyeing will result. Should the boiler become foul, it can be cleaned by using about 2 lb. of whiting and a little urine. The goods on removal are all washed out clean in hot water first and cold afterwards, when they will be ready for blocking.

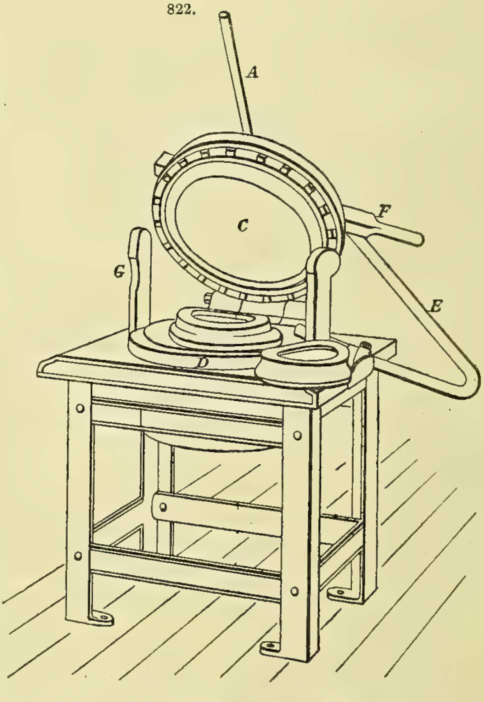
Blocking.—All the goods are removed after dyeing to receive shape at the hands of the "blocker." A ground floor is necessary for this purpose, and good drains must be provided to carry off the large quantity of water used. Steam pipes are laid on to a battery, similar to the one described under the head of planking, allowing 4 men at each. A small bucket containing cold water is placed on the right, and the left hand holds a block of the shape and size required in the finished hat. Steam is turned into the centre cistern, filled with clean water, and heated to 88° (190° F.). To make the felt more pliant and elastic, sometimes a little meal is mixed with the water. Unprincipled workmen, to secure this end, will surreptitiously use alkalies. By this, the work is damaged in dye and stiffening, showing a whiteness after standing for some time in the finished state. Two hats are plunged into the hot water by each workman, as one can be made pliable for working while the other is in process; but not more than two should be in the water at once. Lifting one hat, the workman will pull out the tip, or "unbutton" it. If this is effected thoroughly, the crown will stand sharp in its mould, so long as the stiffening holds good in wear. Should this operation be badly performed, the hat has a tendency to go back to its original shape, as seen when coming from the "former," before planking; and in the trimmer's hands, it will frequently occur that when she puts in the lining with a little flour paste, the hat will spring out of shape, spoiling the article after all the cost of trimming has been incurred. Taking hold of the brim whilst hot, having first placed the block on a pivot so as to raise it about 4 in., the workman thrusts it vigorously down evenly on all sides. Passing a draw-band around the extremity of the block, he turns up what forms the brim, running the cord down on the flat portion of his battery, lined with copper, which retains the heat longer and assists him better in his work. With a small brass runner, grooved to fit the cord into its place, he immerses the hat bodily again in the hot water. Holding the brim firmly with one hand, he breaks it with the other, using his thumb as the fulcrum, and removing all the creases, until, from the cord to the edge of the brim, the hat is quite flat and without "puckers" round the outer edge. Loosening the draw-cord, the hat is lifted from the block, and thrown into cold water to set. This process is applied to all kinds of hats, hard and soft. Other means are employed if hand labour is dispensed with; and of late years, both in America and England, great efforts, with varying success, have been made to supersede this most laborious branch of the trade, as the workmen's hands, by severe scalding and pulling, are frequently disfigured, and the work is not adequately executed. In America, machines are used for breaking the brims and opening the tips, for common goods especially, and are occasionally also applied to fine goods; but the risk is so great in this class of work that it is not advisable to resort to the plan until care and experience have proved its complete adaptability. For common woollen goods and soft hats, it may be used with safety, if care be taken to work the goods through hot water, and to commence the strain from the centre of the tip, until open to the width of the block. The brim-breaker must be worked in the same manner, the hats being taken from the hot water. As this machine acts with a motion much like the opening of an umbrella, it will be understood that it strains the edges of the brim, but should the brim be kept in one position during the operation, or be pressed too far between the brass fingers, the marks will be seen after the goods are finished, and will completely spoil them. The only safe method is to press the brim gently, raising the fingers of the machine, and moving the hat just so far as to take under pressure the portion hitherto unstrained; by this means, the whole brim is evenly broken, and made ready for blocking. Many forms of this machine have been partially perfected, the most successful being one in which the hat-block is placed upon a central spindle, from which radiate ribs, the same as those of an umbrella. Notches are made on the extremities of these ribs, which are jointed so as to produce a partly horizontal motion, whilst fingers clip the outer edge of the hat. The machine is adjustable to any width of brim. Upon a shaft above the block, is attached an iron ring, having the shape and size of the average blocks to be used, and working on a loose swivel. The ring performs in a less effectual manner what the hand-blocker effects by his draw-band, making a close and firm band where the leather of the hat is placed. Taking the hat from the hot water, the workman presses it over the block, seizes the outer edge with the fingers of the machine, draws it to the width of brim for which the machine is set, and brings down over the block the iron ring to form the band, when the blocking is considered complete. Many points require consideration before adopting these machines. For first-class goods, they cannot compete with well-trained hand labour. For medium and common soft and hard goods, where every convenience is at hand, and with workmen who can be depended upon to watch carefully that all the hoods are of one size, rejecting any that are not uniform in this respect, they may and are being worked successfully. But for a small output, and where the other requisite conditions cannot be complied with, it would not be advisable to adopt them. Where these machines are successful, ten times the amount of work can be performed as by hand labour.

Stoving.—The next department is the stove, where all blocked hats are taken to be gently dried. To retain the shape is the great desideratum in this process. If too hot, the hats, being wet, are reduced too quickly by the heat, and, being loaded with water, steam rapidly, and fall in shape, thus destroying all that the blocker has done. Having dried the hoods, it is requisite to strengthen the hard hats. This is effected by taking a small brush, and again pasting on a thin coat of proof, in the inside of the tip as well as the sides, to assist in retaining the shape. If the crown is very sharp and flat, it will be necessary to insert a thin layer of calico, stiffened with proof, and cut round like the crown. This, in pressing, fixes the crown firmly in its place, and holds it tight. With common woollen hard hats, it is usual to pass the outside over a rose gas-jet, to singe the long nap, placing them to damp a little in the air. Singeing is not admissible for soft hats; they are much improved in quality by lying in a cold, damp cellar for some time before using. Hats that are pasted must again be taken to a low stove, to dry the paste before being removed to the stock-room. The best method is to assort all the hats, both as to shape and size, on taking them from this stove, that the operator in the pressing department may take all one sort required for his orders to press at once, thus saving considerable time and labour.

Pressing.—The next process for hard hats, and in many cases for soft ones also, is "pressing." A ground floor is most suitable for this department, as heavy pumps, retorts, presses, and dishes or moulds, are required. The most refined taste is demanded in selecting shapes suitable for the various markets. Having decided upon the shapes to be made in hard hats, blocks are turned in wood, two sizes, and sometimes three sizes, larger than the pattern hat. The moulder casts the shape in iron, called a "dish." Not more than one should be made of each shape decided upon, for it frequently occurs that alterations are necessary, and that these first attempts are useless. On receiving the dishes from the moulder, each should be examined first for blown places in the casting; if any of importance are detected, they should be rejected at once, because a great pressure having to be put upon them, 200 lb. a sq. in., or even more, any flaw will be forced open, thus causing expense and delay. Secondly, the oval and size of each dish should be ascertained to be correct; and lastly, each dish, being ground and glazed internally, requires great care in testing the evenness of the grinding. Should any inequality occur, it will be clearly shown on each hat, and damage the general appearance when finished. It is important that the dish should fit dead to the under plate in the press. This can be decided by placing a straight-edge across the inner ring of the press upon which the dish rests, afterwards applying it to the back of the dish, which is turned to a flat surface. If it is round, or "hump-backed," the first trial of the pressman will break it into pieces. The same thing will occur if it is turned out too hollow. What is desirable is a solid face, if the dishes are to stand the constant strain put upon them. Finding all correct, a slight mark at back and front, to indicate the exact centre, will be found of great service in giving the trimmer a certain guide in fixing in the hat tip or lining, for nothing looks more slovenly than to have the stamp or name on the lining crooked. Each selected dish will have its size plainly marked on, or large figures may be cast in the outer skin of the dish. The selection of a substantial pair of pumps, with a capacious overflow cistern, will greatly assist in turning out a regular quantity of work, many makers being imposed upon in this respect, by machinists advising the use of pumps much too weak for the purpose. These must be secured solidly upon a stone or concrete foundation, screwed firmly to the same by T-bolts socketed into the masonry. At a short distance is fixed a stout iron retort, 6 ft. high, and 2 in. inside diameter being the most useful size. A supply-pipe connects this retort with the pumps, beside a corresponding one to return the overflow. Above the centre of the retort is a pressure-gauge, for indicating to the presser the exact amount of pressure being exerted upon each hat. The press is also connected by a feed-pipe with this retort, and an overflow pipe to return the water, before releasing the pressure from the internal indiarubber bag. A stove, heated by fire or steam, is arranged as near as possible to the press. If used as a fire-stove, a central strip, which divides it into four compartments, is dispensed with, using merely a square chest with wooden ribs, forming a shelf across the centre. Hazel sticks laid across are strong enough to carry the weight of the hats. A solid shelf would burn the hats, and destroy itself quickly. This fire-stove requires the utmost attention on the part of the workman, to keep it at such a heat as will merely soften the proof or substance of shellac, without drawing it to the surface, or the work is at once damaged. On pressing the two hats, for no more must be placed in the fire-stove at once, the wooden cross-pieces are removed and cooled in water, or it will be found that, at the points where the hats have rested, the intense heat has drawn the shellac. This fact has brought the steam-heated stove or "baker" into use wherever there is a steam supply. This stove is composed of an outer jacket, as well as an internal case, divided into four equal compartments, and leaving a steam space between the inner and outer cases. The joints of the steam-chest are made good by a series of bolts, and luted with iron-turnings and sal ammoniac. Immediately adjoining, the chest is connected with a steam-trap, to keep it free from condensed water. For safety, cast-iron should be rejected for this structure, as under a strong direct boiler pressure it would be most dangerous. The cost will be a little more to construct the outer shell of boiler-plate; but safety should be the first consideration. The inner chest may safely be constructed of cast-iron. There is no danger of burning the hats in this arrangement, as in the one heated by fire. Four hats can be under operation at once; the operator, removing the one longest in the oven, presses this first, replacing it by another, to keep up a constant supply so long as he requires to continue pressing.

Many firms press all soft hats the same as hard hats, obtaining a much finer finish by the process, although losing thickness in the feel; still this even, thin consistency is much esteemed in some markets. The pressing of soft hats is a little varied from the treatment of the hard ones. Goods of the size wanted are selected from the damping-cellar, and given time to dry by opening them out singly. By a pipe carried into a chest underneath the dish, steam is admitted to heat the dish in which the hat is going to be pressed, which makes a much finer surface. The dish must never be allowed to get too warm, or it will "punish" the goods considerably, and disappoint those whose expectations have been raised by the repute of this process. The apparatus is shown in Fig. 822.

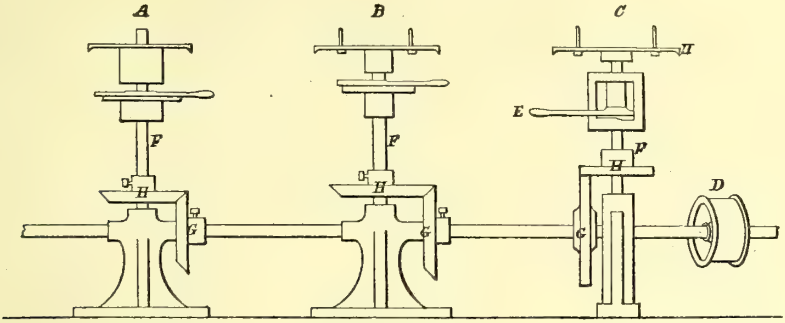
822.



The hat, hot from the steam-oven, is placed in the dish D. The lever A is brought down to a level with D, and the strong spider F is locked in the lug G. E is a strong pipe through which water from the retort is forced into the india-rubber bag C. The machine being locked the full pressure of water is allowed to force itself against the inside of the polished dish, giving the felt the exact form and surface of the pattern inside. On shutting off the water from the inlet pipe, the outlet is opened, drawing the water from the bag, thus freeing the hat from pressure. The press is opened, the hat is removed, and the process is repeated. When properly completed, the hats are ready for the "finisher."

Finishing.—Any room with good light will be suitable. In it are fixed a row of "finishing"-lathes A B C, as shown in Fig. 823. These are driven from D, giving motion to the upright shafts F, by pulleys G H. The underside of the pulley H is covered with leather, to increase the friction, and produce steadiness. The lever E when out of gear raises the pulley H, and, by destroying the frictional contact, stops the machine. The face-plate I, keyed fast to the upright spindle, has screwed to it iron pegs, on which to fix the wooden block having the form of a hat when pressed. On the outer edge of the table that carries these finishing-lathes, iron plates, similar in outline to half the side of a hat, serve to finish the underside of the brim. Turning the hat with one hand and sand-papering with the other, a fine surface is produced, on completing which, the hat is placed upon a block on the pegs on the face-plate I. The machine is then set in motion, and after brushing the hat with a stout brush, the finisher gently applies the sand-paper to the upper side of the brim, side, and crown. The block performing an uneven circle from its oblong shape, demands a nice touch in applying the sand-paper, otherwise the shoulders of the hat will be shaved bare to the proof, the work being spoiled in consequence. The hat is taken from the block, finished by sand-paper with the hand along the sides and crown, and placed again upon the block. Velvet and moleskin velures are used: the velvet one, moistened with water, is placed upon a hot iron, to convert the moisture into steam; this is applied to the outer surface of the hat, after which, the moleskin, or another velvet velure heated on the iron, is again sharply applied. The machine is set in motion after completing the side of the hat, to bring the crown to a regular even polish, finishing the underside of the brim on the brim-plate. "Wools" and fine goods are treated in the same manner. To finish soft hats, a different method is resorted to. Before they can be either pressed or finished, a steaming-bench is used. The block being shaped to the design ordered, the finisher draws the hat over the block, covers it with a tin cap, and softens it by steam. Putting the block on what is called a "spinner," the hat is drawn down, until the tip is free from puckers, a cord or draw-band securing the hat to the edge of the block. Leaving it to cool, another hat is treated in the same manner, and then removed to the finishing-lathe, to pass through the same treatment as the hard goods. If desired, these soft hats can be pressed after this process, when the surface is made very much finer; but they are not pressed until all the damp acquired in finishing has gone off, for if subjected to pressure in such a condition, it will be found that the bodies, when pressed in by the hand, have their felt opened, and look much coarser than before. Soft hats are rounded in the brim, i. e. cut to a size, by a gauged knife, shown at P, in Fig. 828.

823.



Another kind of hat is the "half-stiffened," or "frame" hat, so called from the shape of the brim, being obtained from a wooden or tin frame, made to the style of curl required. The hat in such a case is placed under steam, like the soft ones; the brim is pulled wide to cover the frame, and a draw-band is firmly fastened round a groove made in the frame, to determine the shape of the curl. Thrusting the hat down the centre of the frame, the block for shaping the crown is forced to the tip by a screw in a small iron frame upon which the hat and block rest. The underside of the brim is then sand-papered, before removal, which must not take place before the hat is cool. The finishing-lathe may then complete the hat, as in the other kinds.

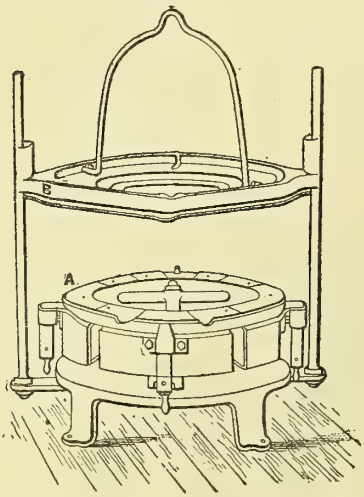
Should the soft hats not be pressed, they will be cut to the width ordered, and curled, either by hand, or by a machine worked by the engine. If finished by hand, use is made of a wooden or metallic gauge Q, Fig. 828, with a steel cutter sliding out to any suitable diameter. Drawing the finished hat over a block, and adjusting the latter upon a cutting-board, the knife *a* is thrust against the hat. Holding the block firmly with the left hand, the right moves the cutter round the hat, paring it clean and level. By inserting a stout cord or leather strap under the edge, turning just sufficient of the felt over this cord with the left hand, and following it closely with a hot iron in the right, half the circle is completed. By turning the block round, the remainder of the curl is finished. The iron must not scorch the felt, as neither the curl nor the binding of the hat will cover it. Should it occur, the effect may be removed by scraping with a knife and steaming afterwards. The hat is then ready for the trimmer.

Trimming and Shaping.—The hard hats coming from the hand of the finisher pass to the shaping department, to receive various treatment, according to the style of curl required in the brim. Should the hats be of common wool, many improved machines are now used in the best establishments to supersede skilled labour. First, the style known as "plain shape," i. e. a hard hat having the brim cut to the size, simply receives a binding, sewn down with an ordinary Thomas' sewing-machine, having the leather and lining sewn in previously. The so-called "Anglesea curl" needs different treatment. However, both styles must first be cut in the brim. To obtain a fine light appearance, the shoulders on the back and front of the hat are cut narrower than the sides and front. If good judgment be displayed in this process, the value of the goods will be much increased. The useful and simple machine shown in O (Fig. 828) effectually performs this operation on both fine and common hats. The machine is firmly fixed on a bench. The plate *a* is shaped to suit the style, giving the exact width on the shoulders; *b* holds the hat firmly by expanding in four parts, the circle being completed by a strong indiarubber band, which adheres firmly to the inside of the hat, and is held in a state of tension by the lever *d*, drawn round a ratchet-wheel and locked by a catch; *c* forms a double lever, with a hinge that allows it to be lifted from the lower part, which is slotted out and marked off in inches, thus making it adjustable for any width of brim. Underneath the upper half of this lever, is a small cutter. After setting the machine, the hat is fixed firmly, as described, by lifting the upper portion of the lever, so that the brim of the hat rests upon the lower. The top lever is then pressed down, forcing the cutter through the felt. At *e*, are fixed two small pulleys, grooved to fit the edge of the plate *a*, running loosely round it. The operator draws the plate *a* with the left hand, and holding it stationary with the right, pulls the lever *f*, connected with the lever *c* above, and thus evenly cuts the entire brim.

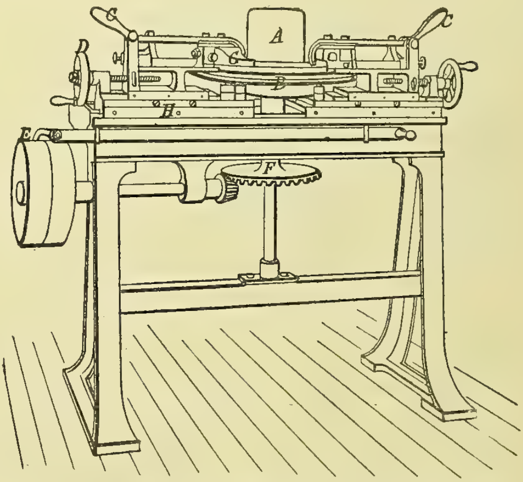
If the hats are rounded for plain shapes, they are at once sent to be trimmed. Those intended to be shaped and bound by hand go to the shaping-room for roll curls. The shaper cuts a piece of swans'-down in a half circle to fit half the hat-brim, and puts this over the brim, wetting it with a sponge, ironing round the outer edge, and curling it with a tool similar to H (Fig. 827). With a chisel or small plane, he shears the edge, to produce a smart appearance. When a dozen of the assorted sizes are complete, they are forwarded for trimming.

The "flat" or "Anglesea" curl is the next in importance, and is the most popular curl used in hard felt hats. It can be pulled up as in the last process by a hand tool, and ironed flat on the outer edge to a sharp angle, the securing of which should be the first object, whether by hand or by machine; if the operation is badly performed, and a thick edge is left, that which should be effective and light in appearance looks clumsy, and more like the former curl spoiled. The shaper conducting this operation by hand pares the curl to $\frac{1}{2}$–$\frac{3}{4}$ in. on the centre of the sides, running it to $\frac{1}{8}$ in. in front, with a clean even sweep of a chisel or plane. This finishes the curl, and the hat is ready for the trimmer. Hand curling is used mostly for very fine work at present, and for silk gossamer-body hats. But where price and quality are considerations, the following processes can be used without skilled labour, and will give fair results, besides saving at least five men's labour in pressing the curls. The press shown in Fig. 822, and described under the head of "pressing," p. 1115, is worked as previously explained, only instead of a dish, D is a mould, constructed in the form of a curl. The hat must have the shellac or proof softened, as by a hot iron, which can be done in the brim-heating apparatus, Fig. 824. The brim in A is heated; the upper ring B is brought down upon it, the brim is heated until soft, and is then placed upon the mould A in the press (Fig. 822). Applying strong pressure, the curl is moulded into shape to produce a sharp edge. A press of similar construction is now in use to produce a feather-edge, without ironing; it works very satisfactorily for medium and common goods, but after such pressing, the curls must be raised by a thin wooden or metallic plough to the angle desired. Cutting the curl to size, the hats are ready for the trimmer.

824.



825.



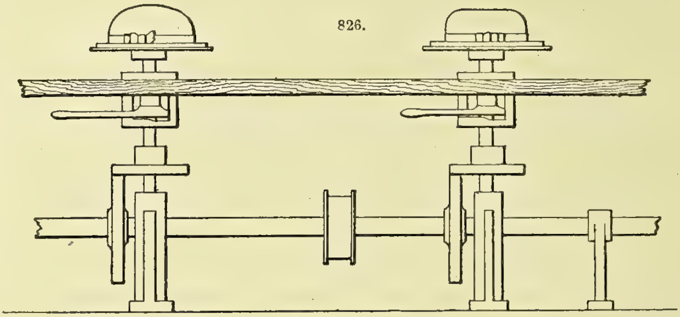
A very elaborate machine, working by hydraulic pressure, and following the lines pursued by hand labour with the hot iron, is shown in Fig. 825. The driving-pulley E gives motion to the upright spindle F. Firmly fixed above the top step, runs a face-plate B, dished out to receive a sunken ring, having the exact form of the hard hat whose brim is to receive an Anglesea or flat curl. A boy can readily be instructed to attend to the machine. The rings are made to suit each size of hat, and may be adjusted in succession to the same face-plate. On the extremity of the spindle F, is secured the expanding block A to fit any size of hat. By drawing back the handle D along the compound slide H, the hat is free to rest upon the sunken ring. Having cut the brim to an approximate size, the two slides attached to the lever C are moved forward to the edge of the felt that is curled over into the sunken ring, for G is so constructed as to double the felt over, and being heated by gas, effectively irons down the whole of the curl. Pressure upon the hot iron is regulated at C. D being used to follow up the curl until completely sunk into the mould or sunken ring, A revolves, turning the hat with it, while G remains stationary. The shape of the hat being oval, presented a difficulty in attempting to iron it down by a circular motion, but this was overcome by a cam, enabling the iron G to follow the exact course of the oval, by means of the compound slide. The machine is complicated, and is expensive to work so far as quantity is concerned. The rings are required to be of all widths and sizes, and the apparatus is suited only to the requirements of a large manufacturer. The small machine illustrated at D (Fig. 827) is one of the most useful heaters for curling plain shapes. Three of these form a set, the circles of each being so designed as to take in several sizes of hat. Under the steam-chamber *a*, is placed a strip of felt, and the same on steam-chest *b*, to prevent the binding of the hats being scorched. Each chamber has an indeepndent steam connection, which requires to be provided with a steam-trap, to prevent any accumulation of condensed water. It is further advisable to have the connecting pipes of such length and construction as will allow of an expansion of a couple of inches. The half of the hat-brim to be curled is put between the lips, as it were, of these two chambers, so far as to cover just the width to be heated. A foot-lever is better than the hand-lever *d*. The lips are pinched close, and the hat when hot is taken out and curled. Very much time is saved by this process, as one hat can be heated whilst another is in work, at the same time doing away with all ironing, and making it easy for juvenile labour. The best way of using the machine, is to make the working bench level with the top side of the steam-chest *b*; by this means, the hat, resting flat upon the bench, can be moved directly into the aperture.

The curling finished, the hats are ready for the shaper. As the hats require trimming, it will be convenient first to follow that process, reverting to this department when finishing the shaping of the brim. In large manufactories, a considerable number of females are employed to trim the goods, as both hard and soft children's and ladies' hats demand a delicacy and lightness of handling only to be obtained by female labour. A commodious well-lit room is requisite for the fineness of the work. The hats being assorted in regular sizes, the trimmer is supplied with the leathers, linings, bands, and bindings, with paper or underlining, as the case may be. These she places upon the hat, lashing in the leathers, being specially careful not to apply too thick a paste around the tops of hard hats, for this has a tendency to make the crown give way in shape, destroying all the previous work, and rendering the hat almost valueless. The markings of the press dishes are very useful to the trimmer, enabling her to determine the exact centre of the hat. The whipping-in of the leathers evenly in the stitches adds much to the character of the work. In measuring out the bands and bindings, a person of great steadiness and firmness is required, so that all odd scraps of silk, &c., are used up, and no more than the exact measure given out, otherwise what has been calculated upon as a profit may be more than lost in this department. Tickets or size labels are gummed on to each hat. Those requiring bindings, such as plain shapes or soft hats, can be bound by Thomas's machine, or fancy-stitched on the band and binding. The most approved method is to drive all the sewing-machines by steam, for they are then more evenly worked than by treadle.

Soft and half-stiffened hats are completed in this department, except brushing and veluring. Hard hats are returned to the shaping-room.

While the operation of curling the hard hats dealt only with the outer edge of the brim, the final one of shaping alters the whole surface. Great experience and refinement of taste can alone ensure satisfactory results. A good light, to enable the shaper to place his work against it, so as to make the lines strike sharp and clear to the eye, is an essential. He places 3 or 4 hats on a steam-chest, heated to soften the shellac of the proof once more; when sufficiently soft, the hat is pulled a little at back and front, and by resting the crown on the bench, the workman uses his thumbs to break the band of the hat all round the leather. Pulling in the curl from the shoulder on the extreme edge, and following the curl up to the body of the hat, prevents any further contraction taking place. Should the work be scamped in this respect, the hat is almost certain to lose its shape, and look very slovenly indeed. With a flat dummy, the back and front of the brim are worked even and straight; a plough is used for the upper side, to blend the curves on the sides when the hat will be finished.

Veluring.—The last process before packing is "veluring," after the hats have cooled. This is best conducted, as is also the packing, in a room free from dust. Good bench accommodation is provided, with a range of veluring-lathes (Fig. 826), of similar construction to the finishing-lathes, driven by engine power. The hats being fixed upon the lathe, the finisher applies a velvet pad; first brushing the dirt from the hat, then damping the velvet, and steaming it upon the gas-stove B (Fig. 827), he starts the lathe, pressing the velure upon the tip and sides of the hat, and afterwards applying a hot velure to give polish and an even surface. Under the brim, he proceeds in the same manner, and this completes the last stage of the manufacture of both soft and hard hats.


826.

In this department, are conducted the boxing and nesting of the hats, in order that no indentations may be made on them, for being placed one upon another and handled roughly is sure to cause damage. The sides of the brims need protection, otherwise the motion backwards and forwards would "fridge" the brims, and on reaching their destination, the hats would be found unfit for sale. The sizes should be marked plainly on each parcel or box, to correspond with the invoice, and a careful register should be kept of every particular of the hat, e. g. colour, brim, curve, band, binding, &c., to ensure exact compliance with orders.

Supplementary Remarks.—Having completed the description of each process as ordinarily conducted, it will be well to supplement it by a few very important hints, which may lead to beneficial and profitable results. For instance, the fulling-stock may be made the vehicle for dyeing or staining all fancy colours, as drabs, beavers, slates, mouse, tan, rosy drabs, and many others. Some makers partially dye, and then complete the staining in these stocks. A useful beaver stain is made of 1¼ lb. copperas and 1 pint iron liquor (pyrolignite of iron) diluted with boiling water, 4 oz. Hofmann's aniline blue, and 4 oz. indigo extract (free from vitriol, or this will turn it green), for 1 doz. hats. Another good beaver brown for the fulling-stocks, for 24 doz. 3-oz. bodies, is 1 lb. common graphite (blacklead), 3 lb. Venetian red, 1 gill indigo extract. A cream-colour for 24 doz. 3-oz. bodies, is 2 lb. red-lead, 2 lb. common terra castle, 2 gills indigo extract in liquor, 3 gills orchil. A fawn-colour for the same hats is 1½ lb. burnt sienna, ground fine, ¾ lb. burnt umber, ¼ gill orchil, ¼ gill indigo extract in liquor. Mouse-colour: 3½ lb. common graphite (blacklead), 2½ lb. best terra castle, 2½ gills indigo extract in liquor, 4 gills orchil, 8 oz. red-lead. An ordinary drab for soft hats: ¾ lb. common graphite, ¾ lb. best do., 3 gills orchil, 2 gills indigo extract; put the graphite into a pan, cover with water, and let down with sulphuric acid at 30° Tw. Light beaver: 2 lb. red-lead, 1 oz. indigo extract, 1 lb. common graphite, 2½ lb. terra castle. Rose: 2¾ lb. commmon graphite, 2 gills indigo extract in liquor, 5 gills orchil. Slate: 4 lb. common graphite, 4 gills indigo extract, 3½ gills orchil. Cinnamon: 3½ lb. red-lead, 2½ lb. best terra castle, 2½ oz. picric acid, ½ gill indigo extract, 3 pints orchil. The picric acid is first dissolved in hot water, and the other ingredients are added.

General Hints.—To give the best results in fine fur hats, all the hoods should be shaved on a lathe before proofing. Many of the best makers assert that this class of goods will retain better colours by being mordanted before placing in the logwood bath.

During the last two years, a demand has arisen for a class of goods for ladies' wear that had not been in demand for 30 years. Many of the old hands had died off, and only a few very far advanced in years could be found to teach the rising generation a process that had almost passed into oblivion in this country, viz. roughening or "napping." In this process, after the ordinary body has been proofed, a woollen or fur body will serve the purpose, a long nap of beaver, otter, nutria, or hare fur, finer than that of which the body is made, is selected; ½ oz. more or less of the uncarroted article is weighed out, being sufficient to cover the whole outside surface of the hat. Taking this with perhaps ⅛ oz. of cotton, the two are completely mixed, either by the "hurdle," or by any other suitable process. The two materials completely blended are laid out upon boards, as evenly as possible. The cotton is used merely to enable the workman to handle the fur, which otherwise would be too thinly spread, and so attenuated of itself, as to preclude its being lifted. This mixture is laid upon the body wet, at the side of the planking-battery. A little water is sprinkled over it, and it is beaten down with a brush. The hood is taken up carefully with this thin coating attached, is lapped up in a piece of woollen or coarse horse-hair cloth, and operated upon lightly, and nearly the same as when planking a body. The principal object to be attained is to get the fibres of the fine fur to penetrate the body of the coarser foundation, and take root, as it were, therein. Much experience and care are demanded of the workman at every motion of his hands, to make the points of each fibre of fur penetrate the body.

So soon as it obtains a secure entry, the fur constantly advances, until after repeated rolling, folding, dipping in hot water, tossing, and unfolding, it separates itself from the cotton. By this motion, the fur gradually obtains a firm lodgment in the solid felt body, leaving behind the cotton, with which it was mixed at the commencement, loose and valueless. The workman who has not had much experience in this class of work may continue the planking too long, until, in fact, the fur works quite through the body, and is lost. Note should be taken that, in every process of planking, the water, though hot, should never boil.

Figs. 827 and 828 show a number of the tools and appliances used in making both felt and silk hats; they are as follows:—A, box-iron for silk hatters; B, gas-stove for veluring both felt and silk hats; C, brim-heater for shaping curl; E, brass for curling brim; F, draw-board for proofing; G, another form of brass for curling; H I, hand-moulds for making fine curl to front of brim; J, dummy for laying the nap of silk hats, and securing roundness on the half-block; K, seaming-block for silk hats; L, hand-plane for paring or cutting the curls before binding; M, cutting-board; N, brim-iron; O, rounding-machine; P, rounding-gauge; R, brim-stretcher; S, brim-brush; T U, split stretching-blocks for silk hats; V, steel measure for soft felt hats; W, steel head-measure; X, wire card, chiefly for silk hats: Y, wet brush for felt finisher; Z, large proof-brush for silk hatter; A′, whalebone gauge for caps.

Silk Hats.—The manufacture of the "silk" or "Paris napped" hat was commenced in England about the year 1835, and became fairly developed by 1840. Being so superior in appearance to the old "beaver" both in style and finish, it soon won public favour, and became generally adopted. But however great an improvement it was upon its predecessor, its introduction was not an unmixed benefit. Although the wearer became possessed of a more graceful-looking hat than previously, the workmen were placed in the unfortunate position of having devoted seven years to acquiring a trade which they now saw was rapidly declining, and eventually doomed to become extinct. The processes of manufacture not being at all similar, the difficulty of merging the one trade into the other was insurmountable to the majority, and many spent the remainder of their lives in the poorhouse.

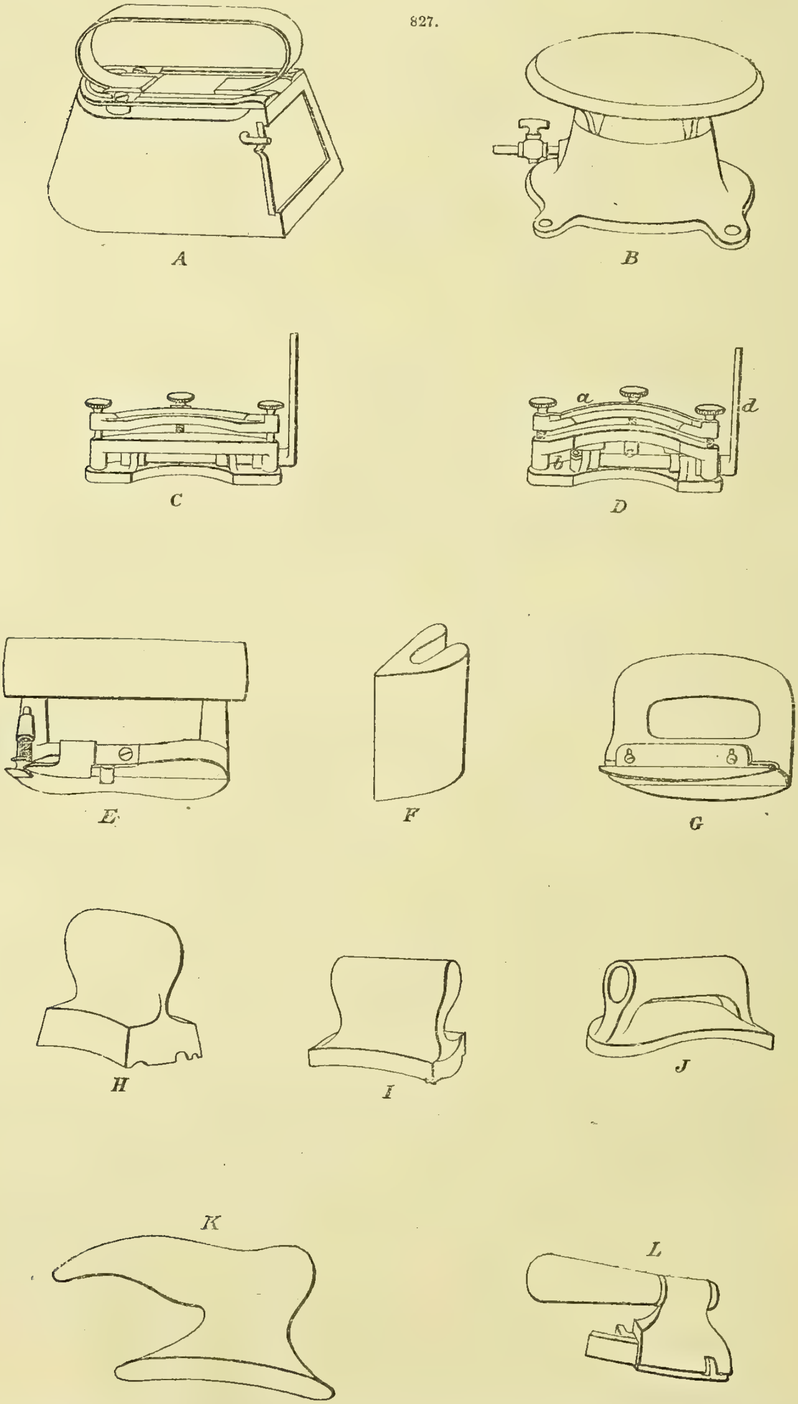
It is unnecessary to describe the various early methods employed in making silk hats. At first a felt body covered with a long-napped plush was used; then a body made of woven "willow grass," stiffened with paste. Soon the short-napped plush was introduced into this country from France, by some French workmen who had been brought over for the purpose of teaching their mode of manufacturing silk hats, and being found so much more suitable, it displaced the long naps, and has been continuously used in various qualities from that time. Shortly after the Paris silk plush was brought into use here, a new and improved body, made upon an entirely new principle, and from altogether different materials, was invented by a workman, and was at once adopted generally. It is the same as that universally in use, and known as the "gossamer body."

Silk hat making is divided into three branches for male labour: body-making, finishing, and shaping; and two minor branches in which women are employed: crown-making and trimming.

Body-making.—The first process, and by no means the least important, is the body-making, as unless the body is well made, it is impossible that durability can be ensured. A length of calico is dipped into the "cougle," or solution of shellac, and allowed to become thoroughly saturated. It is then taken out, and drawn through the half-closed hand to express superfluous cougle, and is next stretched upon a frame, shown at H, Fig. 829. Another length is served in the same manner, and then placed upon the frame over the first piece; the workman finally presses them tightly down upon the pegs of the frame, and with his open hand rubs each surface of the calico until both are in direct apposition, taking care that no blisters, or air bladders, are left upon any part of the surface. Only two substances or pieces are usually put upon the frame when required for the crown, but for brims it is necessary (when it is desired to have them prepared upon the frame) to take a stouter calico, and stretch it upon the frame first; then a still heavier make, a "twill," is put on second, followed by a third piece of the same substance as the first, precisely in the same manner as described for the crown frame. The frame is then put into the drying-room, and allowed to remain until the calico upon it becomes quite dry and stiffened.

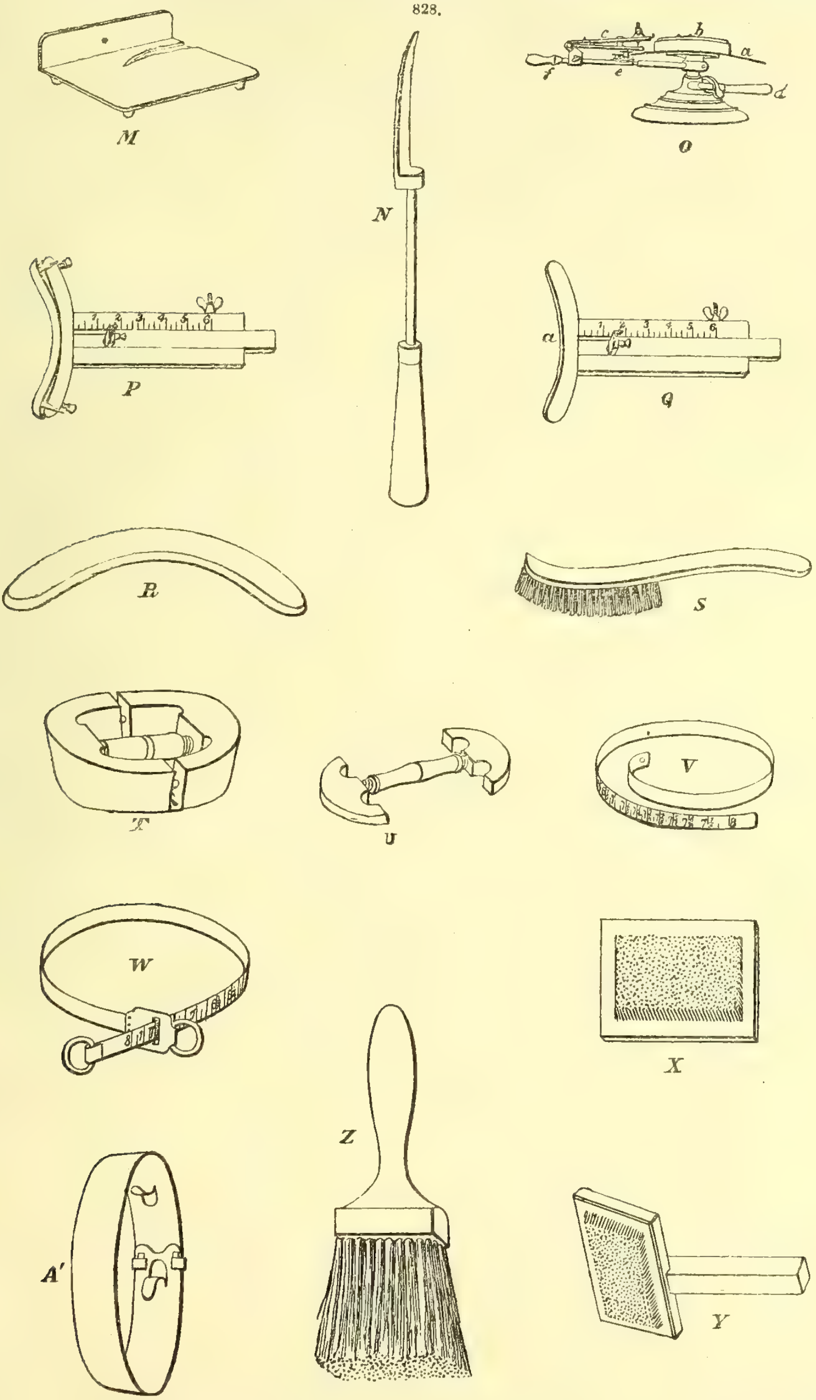
When the prepared calico is ready for use, it is taken off the frame. That intended for crowns is cut into strips of 8 in. wide, these being sufficient to make ½ doz. crowns and tips from one frame. A block of the required shape and size is then taken, and a strip of the prepared calico is cut to the required length, just to go round the block tightly, with ⅛ in. to spare to lap over and form the seam. The two ends are then just lapped, placed upon an iron bar, and next ironed with a hot iron, after which a "dummy" (a small flat iron), used cold, is pressed over it in order to fix the seam. It is lastly damped, and the block G, Fig. 829, is put into it, a piece at a time, first the back and front, then the side pieces, and the middle piece or "boss" last. The boss being forced in, the block assumes its shape, with the gossamer stretched tight around it. The seam being brought about ½ in. to the back of the gossamer, is left above the tip of the block; it is ironed flat, and is then ready for receiving the "tip," which is a piece cut off from that which forms the side crown. This is ironed to the rim, turned over from the side, and fixed thereto. A thin strip of calico stiffened with spirit varnish, and called a "robin," is next ironed on to the edge of the tip. A piece of unstiffened calico or muslin is then placed over, lapping over the crown and tip about ¾ in., the side

827.



crown is brushed over with cougle, and just lapped at the side, the tip being covered in the same manner, trimmed close to the block, and put into the drying-room to remain until thoroughly hardened. The block is made from well-seasoned wood, alder being mostly used. It consists of five pieces, and is turned in a lathe to the shape required. The crown being dry, it is made ready for receiving the brim. The block is taken out, removing the middle piece first, and bending the sides inwards; a thin piece of bone or hard wood, about 1½ in. wide, called a "slip-stick," is passed between the block and the crown, to free any part that may have adhered to the block. A shell made of felted wool is placed inside the crown, and the block is again inserted. The shell is used to prevent the crown adhering to the block while being ironed, which it wouldo therwise do, as the iron is used

828.



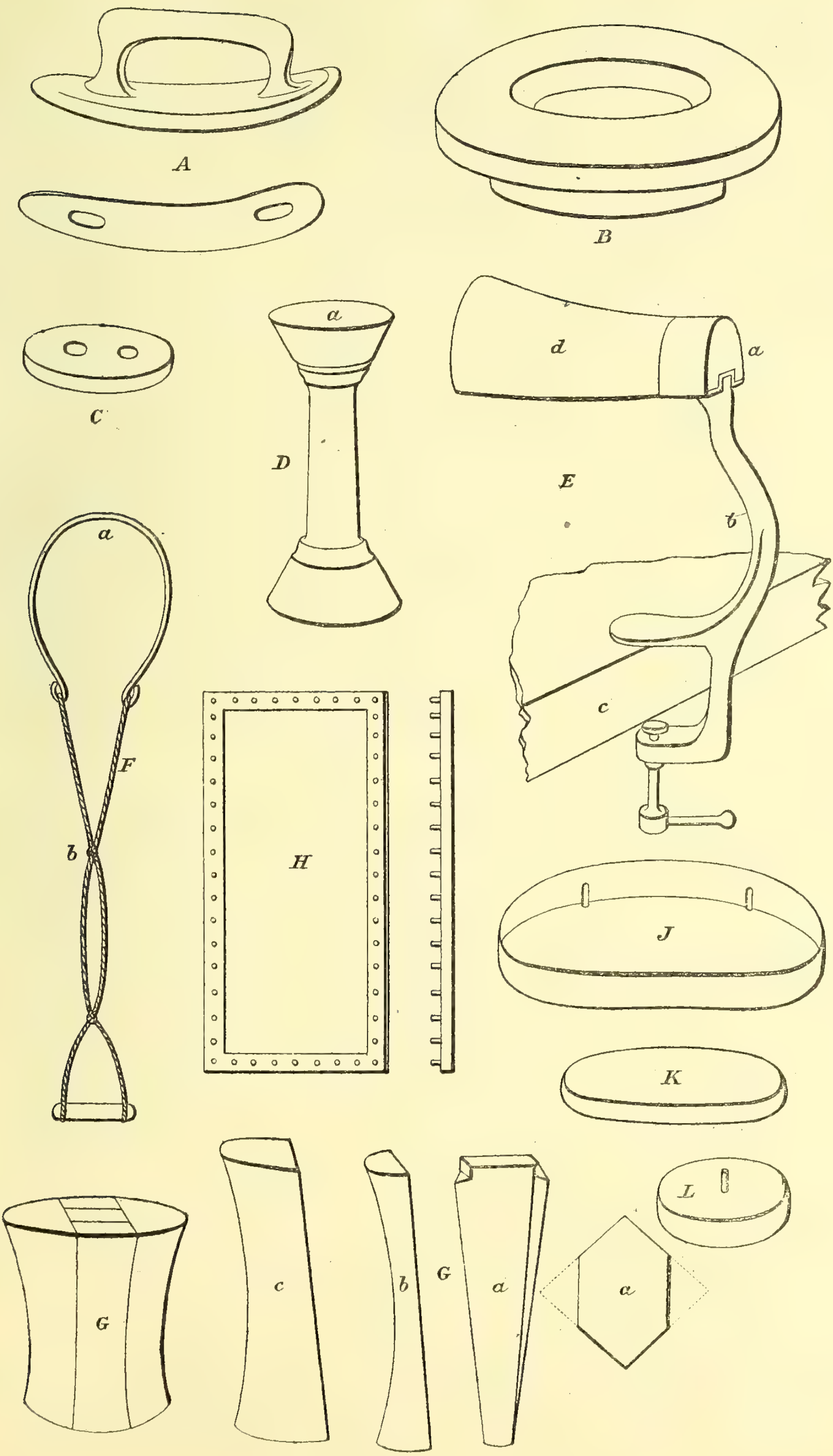
very hot. The crown is laid upon its side, upon the bench or plank, and a little powdered gum damar is sprinkled over the surface, to prevent the iron sticking to the crown. It is ironed until the surface is perfectly smooth and bright all round. The tip is then ironed in the same manner, and the crown is complete, requiring only the brim to form a perfect body.

A light or heavy body is regulated by the number of substances of calico used, or by the weight of cloth. If very light is desired, all muslin for the crown is substituted for calico, and a lighter make of calico is used for the brim. For what are termed " zephyr " bodies, a stout muslin is used for the foundation, with a very light muslin for the cover ; this makes an exceedingly light body, but of course is not so durable, being unable to stand hard wear.

The prepared calico taken from the brim-frame (56 in. by 36 in.) will make 1 doz. brims. One of these is now taken, and the block being placed in the centre, the size of the block is marked upon it. The middle is next cut out to within ½ in. of the mark. The square is then placed upon a piece of board covered with "swans'-down," and is well ironed until it has a smooth surface, and becomes perfectly pliable. A brim-frame J (Fig. 829) is now required. It is of an oval form, arched, and sunk about 3 in. in the centre, but the depth can be altered by inserting thin pieces of wood, called " risers," C (Fig. 829). The block is placed in the centre of the frame, and adjusted to the required dimensions. The softened brim is pulled over the tip of the block, and brought down to the frame, and pressed closely to the side of the crown by the iron dummy; this leaves about ¾ in. of the brim upon the side, which is termed the band. Some thick spirit varnish has been previously brushed upon the crown, round the band, so that when the band is ironed it shall become perfectly secure. The crown being placed upon the side with the brim-frame, kept in position by being pressed against the chest of the workman, the band is well ironed, and afterwards the upper edge is pared, and a robin is ironed over it, and well dummied. The brim is now firmly secured, and only requires ironing upon the underside, to do which the block is taken out, and the brim is placed upon an iron plate let into the plank, and hollowed out so as to allow the band of the hat to be brought up close, in order to obtain a sharp-edged band. The body being now complete, it is put into the drying-room, where it is allowed to remain for several hours. Having been examined and passed as properly made, it is ready to be placed in the hands of the finisher, who covers it with silk.

Finishing.—The silk plush is made into a crown, that is a side and tip, and sewn around the top edge or square of the tip, care being taken in sewing to turn the nap through with the needle, so that the stitches may not be seen when the crown is put on the body. The finisher first prepares for the side seam, by putting a small quantity of cougle on the back of the plush just where it is desired to cut the seam. The nap on the part that is to be last laid is carded back the reverse way. This is done by first damping the part with a sponge and water, and then taking a wire card and carefully drawing the nap back for about 1 in. The iron is next passed over it in order to fix the nap down, and then a straight clean cut is made with scissors. The block is placed inside the body, and thus on a spinner L (Fig. 829), a small circular block of wood with a peg in the centre to enable the block to be easily turned round. The crown is now pulled over the body with the nap outwards, and the tip being perfectly adjusted so that the seam shall come close to the edge, the silk tip is damped all over, and ironed, the body having been previously varnished on the outside with spirit varnish. It will then be adherent to the body. The nap is now carded, so as to take a circular form, narrowing from the outside of the tip to the centre. The side seam is the next consideration. This is made on the left side of the body. The hat being placed on its side, the right is the first to be stuck down diagonally from the tip to the brim. The second or left seam requires the greatest care, as it must be brought close to the edge of the first, without in the least degree lapping over it. This is done about an inch at a time, the edge of the iron being used. When completed, the nap is again carded back, over the edges of the seam, and wetted and ironed. The remainder of the crown has now to be stuck. It must be pulled down to the band, so as to fit the body exactly without creases. It is then ironed over, and well damped, and the nap is brushed and carded perfectly straight, and again ironed with a good hot iron. The nap is well brushed after this, velured with velvet, and again ironed dry. This is to restore the brilliancy of the silk. The silk on the top side of the brim is put on the same way as the crown, with the exception that it is stuck all around the outer edge of the brim with the iron, and the remaining portion is pulled into the band with a stirrup F (Fig. 829), made of copper wire and stout cord or leather. Without the stirrup, it would not be possible to get the silk into the band without creases. The wire is placed over the crown, and the silk is gathered up by it. The foot being placed in the lower loop, it is pulled tight. The nap is brushed, carded, and ironed as before described. It only remains to put on the underside of brim, which is now almost always of merino. Formerly silk plush, corded silk, and satin were commonly used ; but merino remains the most approved material for this purpose. It is put on in one piece, a damp cloth is placed over it, and then ironed, the centre being cut out, leaving about ¾ in. to be turned down on the inside of the band of the hat. Some thick spirit varnish is used to fasten it down.

829.



The hat is now ready for the last process at the hands of the finisher, viz. "half-blocking." A half-block E (Fig. 829) is selected to the shape of the hat, and being fitted to the arm, is screwed upon the plank. The hat is then placed upon it, the block having been previously removed, and ironed without wetting the silk. After the iron, the dummy is passed over the part just ironed, until the body is thoroughly rounded to the half-block, and assumes its proper shape. A velure or polisher made of swans'-down is damped, and the iron placed upon it, to make it very hot. It is then passed over the side crown, which gives great brilliancy to the silk. The tip being ironed on the tip-block D (Fig. 829), and polished in the same manner, the hat is put into paper, the brim is brushed, ironed, and polished on the top side, and the hat is complete so far as the finisher is concerned.

There are two methods of preparing the material for brims: the one already described, termed "water-brims"; and the other "pounced brims." The latter are preferred by some makers, as being more easily curled by the shaper, and with less liability of the substances separating from each other during that process; but a large experience of the use of water-brims has demonstrated their superiority in wear, as they retain their firmness much better than the pounced brims, and can be produced thinner and more "tinny," with less weight, which is a great consideration.

The pounced brim is made in the following manner. A piece of "swans'-down," i. e. a coarse calico, with a nap raised on one side only, is cut to the required size, 13 in. by 12 in., for the ordinary width of brim; the centre is cut out, and it is then placed upon a square board, and some ground shellac is sprinkled evenly over the swans'-down, from a tin box, the lid of which is perforated with small holes. A very hot iron is then passed over the shellac, which melts it and causes it to be absorbed by the swans'-down, thereby stiffening the latter. Another piece of swans'-down is then laid upon that already treated, and served in precisely the same manner, repeating the process until ½ doz. or more pieces have been ironed together. As soon as cold, which is in a few minutes, the pieces are pulled apart, and some cougle is rubbed over each side, after which a piece of plain calico is brushed on, with more cougle, on each side of the pounced swans'-down, and hung up to dry, when another substance of calico is brushed on one or both sides, according to the weight of brim required. When dry, it is ironed well on both sides, and in the same manner as described in the water-brims, the difference being merely in the mode of preparation.

The brim of the body is cut by a rounding-machine, of the same kind as is used for felt hats, to the required width and form, prior to being finished.

There is another mode of finishing which is very similar to that already described, but the block is dispensed with, and the tip-block and half-block are substituted in lieu thereof. There is a little time and trouble saved; but on the whole, it is scarcely so satisfactory a mode, as that of finishing entirely on the block.

Shaping.—This branch has only to do with the brim, viz. its curling and setting. In this, taste and skill are required. Much depends upon the shaper: if he is a good and skilful workman, the style and smartness of the hat are greatly enhanced. The hat, after leaving the finisher, is examined, and if perfect, is passed to the shaper, who gives to it the shape required in the brim, which may be an Anglesea curl, a rolled curl, or a plain-edged curl. If an Anglesea, the hat is placed upon the plank, with the brim downwards, and the iron is passed over the outer edge of the brim on the bare silk, without being wetted, until the brim is made quite soft. The edge is then taken with the thumb and forefinger of the left hand, and pulled up from right to left for about ½ in., lessening the width towards the front and back; it is next pressed over with the foot-dummy until the part turned over lies flat on the brim. The other side is then curled in the same way, and the front and back are just slightly curled on the edge, gradually widening to the side. The curl at the side is then ironed again, slightly raised, made quite free from folds or creases, and pared on the ragged or inner edge. It is now ready for the trimmer. When trimmed, it is returned to the shaper to be completed. He again irons the curl, but must now use a piece of damped swans'-down over the curl to prevent the silk binding from becoming glazed by the iron. The curl is then finally adjusted and raised as required. The hat is now placed upon a brim-warmer, which frequently forms the top of the oven in the shaper's shop. It has an arched top, and it is heated by hot water or steam. In a few minutes, the brim will be sufficiently warmed to render it soft and pliable. The hat is placed on the plank on its tip, with the brim upwards, and is then set, i. e. it is pressed with one hand on each side until it is well rounded, with the front and back dipping down. The brim is now ironed with the damp swans'-down over it, and made perfectly level, and free from indentations or irregularities. A silk band being put upon it to match the binding, it is completed.

The rolled curl only differs from the Anglesea in being round instead of flat, a round pad being used in curling. A plain curl merely has the side edges curled up ⅛ in. at the sides, and is bound with a narrow galloon binding.

Crown-sewing.—The silk plush being marked out to the size required, the crown-maker places the plush upon the tip nap next the body, and cuts it exactly to the size, so as just to cover the edge or square. About ⅛ in. is now turned over, and the sides are taken with about the same amount turned. The sewing is commenced about the middle of one side of the tip, and continued round to the place where it first started, leaving the two ends of the side unsewn, the finisher making the joint there upon the body, as previously explained. The crown must be sewn very neatly and closely upon the back of the plush, the nap being turned evenly through the seam with the needle, otherwise the stitches and seam would be seen. The hat is now trimmed very closely with scissors and the topside of the brim is joined in the same manner, the seam being diagonally across it.

Trimming.—The binding is put on, and the inside lining and leather are put in by the trimmer, requiring neat and careful sewing, the puffed silk lining especially needing care and nicety in drumming it.

Fig. 829 shows some of the tools and appliances employed by silk hatters, in addition to those already illustrated in Figs. 827, 828. They are as follows:—A, shapers' curling-dummy; B, wooden sunken frame, used by body-makers; the surface is covered with zinc; C, wooden "riser" for adjusting the height of the crown, one or more being placed inside the frame; D, tip-block, with felt cover *a*; E: *a*, half-block; *b*, half-block arm; *c*, plank; *d*, felt cover to half-block; F, stirrup: *a*, copper wire; *b*, cord; G, block: *a*, middle piece; *b*, side pieces; *c*, front and back pieces; H, crown-frame, 72 in. × 24 in., with side section showing pegs; the brim-frame is similar, but 56 in. × 36 in.; J, finishers' and shapers' brim-frame; K, how placed on the pegs of J, used by the finisher when putting the silk on the brim; L, spinner.

The various cloths used for hatters' purposes must be free from dressing, and of a porous character, so as to readily admit the cougle. For the crowns: a light Indian shirting, 24 in. wide, for framing; and a light jaconet, 32 in. wide. The side is covered twice, and the tip once for an ordinary hat. For the brims: a stout calico 36 in. wide, and a twill of the same width, two lengths of each being put upon the frame. No covering is required for brims, unless unusual strength is desired. Robbins are of muslin, 32 in. wide. Plushes are of various qualities, the shortness, thickness, and fineness of the nap determining its value. The back is of cotton, and the nap of silk. Nearly the whole of the silk plush used comes from France, although a small quantity is imported from Metz. The plush is 32 in. wide. The tips are cut on the straight; the sides and brims on the "bias." Shellac: the "A C garnet" and "bright button" are mostly used. "Cougle": 28 lb. shellac, 20 oz. ammonia, and 28 qt. water; boil the water, then add the ammonia, and as quickly as possible the shellac, for the ammonia soon escapes; when nearly dissolved, add a few oz. more ammonia, and a little water, letting it down with cold water to a thick consistency; it can be tested by rubbing between the fingers the same as hard felt proof; it is not gauged, but is reduced to the thickness of a thin flour paste. Spirit proof is made as in the case of hard hats. Shellac is let down cold in methylated spirits to the consistency of a thin varnish, for application as a coating to the body after drying, to stick the silk covering and brim, as well as the robins, and to strengthen the band and tip of the hat.

Exports.—The annual value of the hats exported from the United Kingdom amounts to a sum varying between 1 and 1¼ million pounds sterling. The home consumption is represented by a very much higher figure.

(See Fur; Hair; Silk Manufactures; Wool; Woollen Manufactures.) W. M.

HONEY (Fr., *Miel*; Ger., *Honig*).

Honey is a substance possessing a pleasant saccharine taste, produced from the nectar of flowers by the aid of certain insects, of which the bee is the most important and familiar. The saccharine matter is obtained from flowers in infinitesimal proportions, about 2½ million flowers being required to contribute 1 lb. of honey. The nectar of flowers contains cane-sugar or saccharose ($C_{12}H_{22}O_{11}$), which is converted, during or after its retention by the insect, into "inverted sugar," or a compound of dextro-glucose (dextrose) and læva-glucose (lævulose), both of which are represented by the formula $C_{12}H_{24}O_{12}$ or $C_6H_{12}O_6$ (see Sugar). The presence of cane-sugar in honey is as stoutly denied by some chemists as it is asserted by others. This disagreement may perhaps result from the examination of samples of different ages. Dr. J. Campbell Brown gives the following analyses of genuine bee-honey:—

	English.	Welsh.	Normandy.	German.	Greek.	Lisbon.	Jamaica.	California.	Mexican.
Water expelled at 100° (212° F.)	19·1	16·4	15·5	19·11	19·8	18·8	19·46	17·9	18·47
Water expelled at much higher temp., and loss	7·6	6·56	4·95	11·0	7·8	6·66	7·58	8·13	10·03
Lævulose	33·6	37·2	36·88	33·14	40·0	37·26	33·19	37·85	35·96
Dextrose	36·55	39·7	42·5	36·58	32·2	34·94	35·21	36·01	35·47
Cane-sugar (?)	doubtful	none	none	none	none	1·2	2·2	none	doubtful
Wax, pollen, and insoluble matter	good trace	trace	slight trace	trace	0·05	1·0 nearly	2·1	good trace	trace
Mineral matter	0·15	0·14	0·17	0·17	0·15	0·14	0·26	0·11	0·07

The honey of the honey-wasp of Tropical America (*Polybia apicipennis*) yields large crystals of cane-sugar; that of the honey-ant of Mexico (*Myrmecocystus mexicanus*) is nearly a pure solution of uncrystallizable sugar ($C_6H_{14}O_7$); while the subterranean *tazma* honey of Ethiopia contains 32 per cent. of mixed fermentable sugars, and 28 per cent. of dextrose, with no trace of cane-sugar.

Wild honey is collected by primitive peoples in almost all climes which favour the growth of the necessary flowers. The *tazma* honey is deposited without wax by an insect resembling a large mosquito, in subterranean cavities; it is sought for by the natives of Ethiopia, and used by them to cure throat-diseases. The honey-making ant of Texas and New Mexico is very abundant in the neighbourhood of Santa Fé. The Mexicans esteem this honey very highly, and use it not only as food, but as a medicinal agent. Very little has been done in the way of domesticating or cultivating the two honey-producing insects just alluded to, and the same may be said of the honey-wasp of the American tropics.

The familiar honey-bee is of two species, *Apis mellifica* and *A. ligustica*. The former, which is the most widely known and the most highly prized as a honey-maker, is said to be a native of Asia, whence it has spread over all Europe and a great portion of N. America, and has been introduced with signal success into our S. African and Australian colonies, and many of the islands in the S. Pacific.

Apiculture has advanced considerably in France of late years, and the number of cultivated swarms of bees in that country is now placed at 2–2½ millions. The industry is becoming more general, and owners of more than 400–500 colonies are rare. The production of honey and wax is now valued at 22–23 million francs annually, while the yield of honey from each swarm has grown from 15–16 kilo. to an average of 20–25 kilo. The introduction of the Ligurian bee is receiving much attention. Of the 2,073,703 swarms officially returned in France at the end of 1873, there were 96,038 in Ille-et-Vilaine, 63,207 in Finistère, 60,000 in Côtes-du-Nord, and over 40,000 in Ardèche, Loire-Inférieure, Manche, Morbihan, and Saône-et-Loire. The products of Gâtinais and Brittany are most renowned. The total yield of honey in France in 1873 was 93,112 metric quintals (of 1·96 cwt.). The export of honey from Honfleur, Trouville, &c., was 11 tons in 1876, and 10 tons in 1877. In some districts of Switzerland, bee-keeping is conducted with great energy and success, and instructions are widely circulated by paid lecturers every year. The local consumption of honey is too great to leave any for export. The German government goes so far as to compel all schoolmasters to pass an examination in apiculture, besides fostering the industry in many other ways. Germany (including Hanover and Hesse Cassel), in 1873, had a total of 1,453,764 stocks; Bavaria, 338,897. Somewhat behind are Austria and Hungary in this respect, yet the exports of honey from Vienna were 5163 metric centners (of 110¼ lb.) in 1877, 301,695 in 1878, and 321,849 in 1879; and from Fiume (including wax), 594 cwt. in 1877, and 1224 cwt. in 1878. In ordinary seasons, Servia produces about 5000*l.* worth of honey for export, besides the large quantity consumed locally. The peasants of Poland, Russia, and Siberia, are most industrious apiarians. A number of systems are in vogue in different parts of the country; at Plock, in Ostrolenka, and in the woody part of Lithuania called Polesie, bees are reared in excavated tree-trunks in the forests. The famous "Kovno" or "lipiec" honey acquires its flavour from the flowers of the linden-tree, so abundant in the Lithuanian woods. In this province (Kovno), the Tchmude tribe is almost exclusively occupied with bee-keeping. The industry flourishes also in the Altai mountains, and is followed by the Meretinzes and Grusinians in the Caucasus. The Russian province of Pultowa has about 500,000 stocks, and Ekaterinoslov, 400,000. The annual honey production of European Russia is placed at 600,000–700,000 lb. Italy produces large quantities of honey, though the peasants are very backward in apiculture. The total yield in 1868 was as follows:—Piedmont and Liguria, 380,000 kilo.; Lombardy, 179,880; Venetia, 174,160; Emilia, Umbria and the Marches, 189,840; other provinces, 600,000. The best are from Bormio, in Lombardy, from Empoli, in Tuscany, and from Otranto. Immense quantities of honey were formerly produced in Corsica; much is still collected there, but, except the small proportion obtained in early spring, it acquires such a bitter flavour, from the arbutus-blossoms which the bees frequent, as to be scarcely edible. Grecian honey has been celebrated from the earliest times, but apiculture is quite neglected by the modern Greeks. Syra, in 1877, exported 167*l.* worth of honey to France, and 160*l.* to the Danubian Principalities; and in 1878, 172*l.* to Turkey, 106*l.* to Great Britain, 82*l.* to Egypt, 55*l.* to Austria, and 7*l.* to Italy. In Asia Minor, very large quantities of honey are produced, chiefly for local consumption; the port of Dedeagatch shipped 80 barrels, value 200*l.*, in 1879. The natives of many parts of India are most industrious bee-keepers. But the New World bids fair to eclipse all competitors in the science of bee-rearing and the production of honey. In the United States, honey-raising is a distinct industry, and men are found who own 2000–12,000 swarms, which they farm out to owners of fruit-gardens during the blossoming season. The orangeries and other orchards of Florida, and the gardens of California, offer the best inducements, but the culture is by no means confined to those states. Florida, in 1878, produced over 170,000 lb. of honey; and one bee-farm in San Diego Co., California, afforded 150,000 lb. of honey in 1874. Every scientific contrivance has been adopted, and some bee-farmers despatch floating bee-houses along suitable rivers, to take advantage of the progression of the seasons, and supply the bees with a succession of flowers. It is even proposed to send the swarms to the W. Indies during the winter. Already very large quantities of honey are produced in the W. Indies, but it is chiefly in the foreign islands, and our colonists there have not shown much zeal in adopting this most remunerative culture, despite the almost unsurpassed conditions which it presents. San Domingo, in 1878, exported 38,770 gal. of honey to the United States; and in 1879, 506,640 gal. to the United States, and 2700 gal. to France. Chili produces 5000*l.* worth of honey and wax yearly, which is mostly exported.

The production of honey in the United Kingdom is quite trifling, and nowhere is bee-keeping so little understood, and so little practised as an industry, though the conditions for its success are almost everywhere present, and the profits very large. On the other hand, it must not be supposed that the present high prices of honey would be maintained in the face of a greatly increased production, such as would result from anything like universal bee-farming. Of course, if honey could be produced at a price to compete with fruit preserves, its consumption would immensely increase. But this is very doubtful, considering the long period during which the bees would need feeding, and the uncertainty of our summers. In our tropical colonies, there is much wider scope and better prospect for the industry. Everywhere the indirect benefit conferred by bees in fertilizing the flowers of various crops is of great importance.

Omitting all questions relating to the natural history of the bee, which will be found discussed at length in the works cited at the end of this article, the following remarks relate to the construction of hives, and the management of apiaries, with a view to the most economic production of honey. The swarm is first hived in an ordinary straw "skep"; in the evening, the settled bees are suddenly shaken down into one of the modern improved hives now to be described.

The "Woodbury" hive is the first English adaptation of the principles advocated by Dzierzon and Langstroth. It consists of a square wooden box, $14\frac{1}{2}$ in. inside diameter, 9 in. deep, with a movable cover having a feeding-hole $2\frac{1}{2}$ in. wide, closed when not in use. The floor-board is 18 in. square, with an entrance 4 in. long × $\frac{3}{8}$ in. deep, with a step projecting 3–4 in. for the bees to alight upon. The interior space is equally apportioned to 10 frames, for supporting the combs. These frames are of thin lath, $\frac{7}{8}$ in. wide; the top bars are $15\frac{1}{4}$ in. long × $\frac{3}{8}$ in. thick, and the sides and bottom rails are $\frac{5}{16}$ in. thick. The space alternating with the bar is thus $\frac{3}{8}$ in. A movable upper storey or "super," 3–5 in. high, is added as a honey-store; this is separated from the hive by replacing the cover or "crown-board" by a thin board or "adapter," having long slits $\frac{3}{16}$ in. wide near each end, for admitting the workers, while excluding the queen and drones. The whole is crowned by a wooden ridge-roof. A much improved modification of this is the "Cheshire" hive. The natural heat of the inmates is conserved by double walls with an air space between. Woodbury frames are retained, but rested upon zinc edges, to prevent the bees fixing them. The floor-board moves in grooves, and the entrance is provided with sliding-shutters. The old straw skep is very inferior; it should at all events have a round hole $2\frac{1}{2}$ in. in diameter in the centre of the crown, to admit the bees to the super, and facilitate feeding them. Glass hives are admissible only for purposes of observation; one of the best forms is that known as the "Woodbury unicomb." The first essential condition in all hives is that they shall exclude the wet, and afford protection against changes of temperature. The next consideration is the existence of every facility for the construction of the combs and the rearing of the young bees, as well as the inspection and removal of the combs when required.

During bad weather immediately following the hiving of a swarm, the latter must be fed. A wide-mouthed bottle is filled with syrup, and closed by a double thickness of fine muslin, or by inversion over a perforated support, placed above the feeding-hole in the crown-board. In cold weather, this food is replaced by a sweet produced by boiling 1 lb. of loaf-sugar in $\frac{1}{2}$ pint of water, and adding a little vinegar to prevent crystallization. Plentiful and judicious feeding is most necessary for successful bee-keeping. Abundance of water, fresh or stale, is equally essential.

The objects of the apiarian are threefold:—(1) the prosperity and multiplication of the colonies, (2) stimulation to increased production, and (3) the easy removal of the products without inconvenience to the bees. A rapid increase of stocks and a large production of honey are incompatible, and one of the two objects must be made subservient to the other by suitable management. The former is favoured by artificial swarming, i. e. by hastening the departure of the swarm. In the case of frame-hives, which are the only proper kind, this is effected in the following manner:—The frames are first removed, and the queen is sought for; when found, she is transported with the frame to the centre of a new hive, and is flanked on each side by a comb containing sealed brood. Both hives are then filled with fresh frames and empty combs, or even guide-combs; sufficient bees to form a large swarm are then shaken into, or at the entrance of, the new hive, where all the young ones will remain. This (the queen-) hive is then removed to a distance, and the old one is reinstated; into the latter, will come such of its former occupants as did not remove to the new hive. Feeding on syrup in early spring stimulates the queen to lay, and thus swarms may be thrown off early and rapidly. If a young fertile queen be supplied immediately after a swarming has taken place, the hive will soon be ready to repeat it.

When a large production of honey is aimed at, swarming must be controlled as far as possible. Success is generally secured by putting a super on the hive, before the bees have constructed queen-cells, and made other preparations. The combs are removed on the frames as fast as they are filled, and are then emptied and returned. This is much facilitated by the use of a simple apparatus termed a "honey-extractor," which is made in several forms, but all on one principle. The full combs, with their cells uncapped, are placed in a cylindrical metallic receiver, with their mouths abutting on walls of wire-netting attached to a framework. The latter is made to revolve, when the centrifugal force dislodges the honey, which falls into the receiver. The combs are thus made available for immediate re-use,—a double gain, as the collection of honey is rendered continuous, and the bees do not need to consume large quantities of honey for the formation of new combs. When it is desirable to economize the space of the supers for honey-gathering purposes, the bees may be induced to build comb there by introducing some clean white pieces, always taking care to warm the supers by padding or wrapping. At the end of the season, all honey may be removed, if the bees are fed regularly with syrup, which is much less valuable, but equally good food; otherwise, at least 15 lb. of sealed combs must be left for winter provision.

As to the profit of bee-keeping, it is only necessary to say that, beyond the first cost of a swarm and hive, the expenses are but trifling. Supposing a guinea be paid for a swarm, at the end of five years the net profit arising from the sale of the products should amount to 50–60*l.*, in addition to the possession of 5 new stocks. In America, one stock has given as much as 600 lb. of honey in one season, and 200–300 lb. is quite common. Chilian honey is sold in the London market at 30–70*s.* a cwt., and Jamaican at 35–60*s.* Our imports of honey in 1870 were valued at 28,121*l.*; since then, statistics have not been published, but the amount has doubtless increased.

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(See Sugar; Wax—Beeswax.)

HOPS (Fr., *Houblons*; Ger., *Hopfen*).

The term "hops" is given to the leafy, cone-like catkins, or imbricated heads ("strobili"), of the hop-plant (*Humulus Lupulus*), for the sake of which many varieties of it are cultivated.

Hop-growing requires a moderately warm climate. In this country, a south-east aspect is most suitable, with shelter from the westerly gales of autumn. The selection of soil will depend upon the kind of hop to be grown. The Golding will succeed best on dry friable soils, with gravelly or rocky subsoil, as in the hilly districts of E. and Mid-Kent. Mathon, Grapes, and White, prefer stronger soils, as the deep lands of the valley of the Teme, and the Weald. The good but delicate Cooper's White requires a good strong loam. The land must be thoroughly drained. Preference is given to old pasture; this is trenched two spits deep, the turf is placed downwards and the surface is harrowed and rolled. When planting in tilled land, the latter is ploughed 10 in. deep, and subsoil-ploughed as deep as possible. The land being prepared, the arrangement of the rows, and distance between the plants, are decided upon. The disposition may be angular or square. The rows are usually 7–8 ft. apart, with 2½–3 ft. between the plants. The holes are first staked out, to ensure regularity, and are then dug 2 ft. in diameter and 2 ft. deep, the top earth being placed on one side, and the bottom soil on the other. The good top earth is again filled into the hole, and rich manure is added. When the soil has settled, planting may commence. Bedded or yearling sets, 5–6 in. long, prepared from old stools, and with two joints or eyes, are the best; cuttings entail the loss of a year. One male to 100 females is usual. A hole 2 in. wide and 4–5 in. deep is cut in two sides of each hillock. If the plants are weak, these may be put into one hillock. The head of each root is brought as close as possible to the stick, and some good, fine soil is put round, and made firm by the foot. A 20-acre plantation may be apportioned as follows:—Cooper's White, 5 acres (or Cooper's 3, and Jones' 2); Mathon's 6; Golding's, 6–7; Grapes, 2–3. In this way, the crop may be gathered by degrees, as the different kinds mature, commencing with Cooper's or Jones', and finishing with the hardy Grapes; but the proportions should accord with the suitability of the land. If only one variety be grown, picking must either commence prematurely, or be protracted beyond proper limits. The crop should be secured in 3–4 weeks at the utmost.

In 2–3 weeks after planting, the bines begin to appear, and pitching the poles commences. The size of the poles may be 8 ft. for Jones', 10–12 ft. for Grapes, 12 ft. for Cooper's, 12–14 ft. for Mathon's, and 15 ft. for Golding's. Usually 4 poles are allowed to each hill at 7 ft. apart, and 2 bines to each pole; when 3 poles are used, the bines may be distributed in two 2's and a 3. The next step is tying; but before commencing this, the tier proceeds to eradicate all rank, hollow bines. When the hops are tied, the ground is worked both ways with the nidget or scuffle, followed by the harrow; the workings should be finished by the 1st–10th July. Potatoes and mangold are often planted between the rows, and cattle-cabbage between the hills; in this case, extra manuring is of course necessary. A better plan is to grow turnips, and feed off.

The hops are ready for pulling when they acquire a strong scent, and the catkins become firm and brown. This occurs in early seasons about the 1st–8th September; in late ones, 15th–20th. The bines are cut level with the ground, the poles are lowered, and the hops are picked off as rapidly as possible, for conveyance to the drying-kiln, such arrangements being made as will ensure their not having to wait 5–6 hours, or they may ferment and spoil. The drying is conducted in special kilns or "oasts," by means of a current of hot air being passed continuously through them. The process should occupy about 12 hours, at a temperature not exceeding 44°–46° (112°–115° F.). When the hops are dry, the fire is lowered, and they are allowed to remain till they become soft, when they are removed to the cooling-room, and will be fit for bagging next day. The latter operation is now generally performed by a machine.

The cost of cultivating 1 acre of hops is thus stated:—Yearly charge for poles, 5*l.*; ploughing down, 10*s.*; digging slips, or portion not ploughed, 5*s.*; cutting, picking up and burying roots, 4*s.*; spreading poles, 2*s.*; pitching or setting poles, 12*s.*; tying, 8*s.*; nidgeting or scuffling 4 times, 1*l.*; harrowing 4 times, 6*s.*; forking round hills, and hilling up, 5*s.*; stripping and piling poles, 8*s.*; resharpening broken poles, 3*s.*; ploughing up before winter, 10*s.*; manuring with 20 loads dung at 8*s.*, 8*l.*; summer manuring, 4*l.*; ladder tying, 2*s.*; total, 21*l.* 15*s.* By digging instead of ploughing, 15*s.* more will be added. The cost often rises as high as 35*l.* an acre for the whole culture and harvesting of the crop, and in some cases even to 60*l.* The returns are exceedingly unreliable, ranging from 1 to 13 cwt. an acre. A plantation should last at least 20 years, and some gardens have been in existence over 300 years.

The hop-plant is found wild, especially in thickets on the banks of streams, throughout Europe, from Spain, Sicily, and Greece, to Scandinavia, extending also to the Caucasus, the S. Caspian region, and through Central and S. Siberia, to the Altai Mountains. It has been introduced into India, N. America, Brazil, and the Australian Colonies. The cultivation in the United Kingdom was distributed in 1875 as follows:—Kent, 43,614 acres; Sussex, 11,360; Hereford, 5984; Hants, 3059; Worcester, 2468; Surrey, 2313; other districts, 373; total, 69,171. In Continental Europe, hops are most largely produced in Bavaria, Würtemberg, Belgium, and France. The estimated area occupied by them in 1876 was:—Germany, 94,775 acres (Bavaria, 52,000; Würtemberg, 12,500; Baden, 4000); Austria, 19,277; Belgium, 16,250; France, 10,000; the remainder of Europe, 1547. In 1877, Vienna exported 21,816 metric centners (of 110¼ lb.); in 1878, 15,529; in 1879, 28,772. Antwerp, in 1878, exported 629,352 kilo. to England.

Laudable efforts have been made for some time past to establish hop-growing in Cashmere and in the Himálayas, and there is fair prospect of ultimate success. In the United States, the culture has a pretty wide distribution. The crop of 1874 was estimated as follows:—New York, 50,000 bales; Wisconsin, 22,000; California, 5000; Michigan, 5000; other states, 15,000; total, 97,000. The total estimate for 1879 was 110,000 bales; and for 1880, 120,000–125,000. In Canada, frosts interfere much with the crop. The cultivation started in the colony of San Leopoldo, in the Brazilian province of Rio Grande do Sul, promises well. In Tasmania, hop-growing is now a well-established and thriving industry; and Victoria, South Australia, and New Zealand are not far behind.

The scarcity of hops in unfavourable seasons, and their high price at all times, has led to their frequent adulteration and to many substitutes being proposed for them. Among the adulterants are found many plants possessing powerful and even poisonous properties, while others communicate only a strong bitter flavour. As substitutes, principally two plants have been suggested, and experimentally used:—(1) The fruit of the shrubby trefoil (*Ptelea trifoliata*), said, in both France and America, to give an amber ale possessing a flavour quite equal to that of Strasburg beer; and (2) the leaves of the bog-bean (*Menyanthes trifoliata*), gathered in spring, and dried in the shade, used in Germany. Neither possesses all the valuable properties of the hop.

Besides our own production of hops, we import largely; our imports in 1879 were:—From the United States, 108,306 cwt., 496,886*l.*; Belgium, 63,485 cwt., 262,372*l.*; Germany, 50,567 cwt., 237,618*l.*; Holland, 26,796 cwt., 162,518*l.*; France, 9234 cwt., 41,462*l.*; British N. America, 3813 cwt., 14,596*l.*; other countries, 564 cwt., 486*l.*; total, 262,765 cwt., 1,217,938*l.* The prices fluctuate exceedingly; the approximate relative values in the London market are:—Kent, 4*l.* 10*s.*–11*l.* a cwt.; Sussex, 4*l.* 10*s.*–10*l.* 10*s.*; Farnham, 6*l.*–11*l.* 15*s.*; Farnham country, 6*l.*–11*l.* 11*s.*; American, 8*l.*–11*l.*; Belgian, 4*l.*–5*l.*; old, all kinds, 1*l.*–3*l.* 10*s.*

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(See Beverages—Beer.)

HORN (Fr., *Corne*; Ger., *Horn*).

The term "horn" is generally applied to any hard body projecting from the head of an animal, terminating in a point, and serviceable as a weapon. Technically, horns consist of very different substances, and belong to two organic systems, as distinct from each other as either is from the teeth. The horns of deer consist of bone, and are processes of the frontal bone; those of the giraffe are independent bones or "epiphyses," covered by hairy skin; those of oxen, sheep, and antelopes are "apophyses" of the frontal bone, covered by "corium," and by a sheath of true horny material; only the horns of the rhinoceros are composed entirely of horny matter, which is disposed in longitudinal fibres, so that the horn seems rather to consist of coarse bristles compactly matted together in the form of an elongated sub-compressed cone. It is curious that the horns of wild animals are always more fully developed than in domesticated races, and that with all our improvements in the breeding of cattle, no advance has been made in the size or texture of the horns.

Horns are rendered eminently applicable to a number of purposes by reason of their toughness, elasticity, and flexibility, together with their property of softening under heat, and their capabilities of being welded and moulded into various forms under pressure. The immense horns of the African ox, or Cape buffalo, of the Java buffalo, and of the Arnee buffalo of India, are the most valuable. About one-fifth of our imports of these horns is used for making combs, and knife- and cutlass-handles, while a small portion is converted into shoe-lifts, scoops, cattle-drenches, drinking-cups, &c. The solid horn tips and the hoofs of cattle are made into buttons (see Buttons).

Horn Manufactures: Combs.—Horns which are to be manufactured are first thrown into water, by which slight putrefaction is caused, ammonia is liberated, and the horn begins to soften; the softening is then continued by immersion in an acid bath, for a period of about 2 weeks. When sufficiently soft, they are cleaned, and split into two parts by a circular saw. These slices are introduced between heated plates, and the whole is subjected to a pressure of several tons a sq. in. The plates may bear devices, or be of varying form, thus producing at once any desired effect. The horn may then be dyed black or brown by dipping it into a bath containing a weak solution of mercury or lead salts, and rubbing on hydrosulphate of ammonia; or it may be mordanted in an iron-bath, and dyed by logwood. Fancy markings are produced by immersing the horn in a bath of lead salt, and then in hydrochloric acid, thus forming white lines in the interstices of the horn.

The manufacture of combs is by far the most important application of horn. The laminatory character of the horn, its very diversely running grain, and the raising up of the fibres by the use of the various tools, render it very difficult to apply machinery in its conversion, and the large amount of hand-labour required helps to cause the proportionately high price of the manufactured article.

The softened horn is first split lengthwise in the direction of the grain. The split horn is then warmed in hot water, opened out flat, laid between cold iron plates, and pressed level. If the goods are to be subsequently stained, the slices are further placed between hot steel plates, and very strongly pressed, to reduce the thickness and destroy the superficial grain. The prepared slices are next stamped out by cutters, arranged to form as many combs as possible, of various sizes and shapes, so as to fully economize the material. The slices are again pressed and straightened, and ground, ready for cutting the teeth, which operation is performed by a "parting-engine," or die-stamping machine, in the case of coarse combs, and by circular saws in that of fine-toothed combs.

Commerce in Horns.—Vienna exported 22,604 metric centners (of 110¼ lb.) of horns in 1877, and 32,255 in 1878. Poti exported 17 *poods* (of 36 lb.) of buffalo-horns, and 155 *poods* of deer-horns, in 1877–8. Canton exported horns to the value of 17,248 *taels* in 1878. Newchang exported 1095 pairs of old deer-horns in 1877, and 1034 in 1878. Hankow exported 1935 *piculs* (of 133⅓ lb.) of cow-horns in 1878. Taiwan exported 47 cwt. of cow- and buffalo-horns in 1878. Kiungchow, exported 275½ *piculs* of horn in 1877, and 432 *piculs* in 1878. Shanghae exported, in 1878, 2854 *piculs* of cow- and buffalo-horns, 175 *piculs* of chamois-horns, 298 pairs of young deer-horns, and 48 *piculs* of old deer-horns. Algiers exported 1,274,019 kilo. of horns and hoofs in 1877, and 1,415,850 kilo. in 1878. Guatemala, in 1878, exported 368 quintals to the United States. Pernambuco, in 1877–8, exported 520 hundreds of horns to Great Britain, and 59 hundreds to Portugal. Santos, in 1879, exported 44,430 kilo. of ox-horns to Europe.

Our imports of horns in 1879 were as follows:—From Bengal and Burmah, 654 tons, value 21,001*l.*; Bombay and Scinde, 569 tons, 19,192*l.*; Australia, 485 tons, 14,102*l.*; United States, 451 tons, 6778*l.*; Madras, 373 tons, 15,172*l.*; Straits Settlements, 305 tons, 11,550*l.*; France, 270 tons, 10,285*l.*; Argentine Republic, 245 tons, 7049*l.*; British S. Africa, 223 tons, 11,365*l.*; Brazil, 178 tons, 6670*l.*; Uruguay, 137 tons, 5207*l.*; Ceylon, 96 tons, 5556*l.*; other countries, 654 tons, 17,882*l.*; total, 4640 tons, 151,809*l.* The approximate values are:—S. American ox, 35–80*s.* a 100; ditto cow, 15–35*s.*; Cape, 35–120*s.*; Australian, 6–65*s.*; Deer, E. Indian, 40–120*s.* a cwt.; Buffalo, E. Indian, 20–60*s.*; tips, E. Indian, &c., 18–40*s.*; ditto, N. American, 10–75*s.*

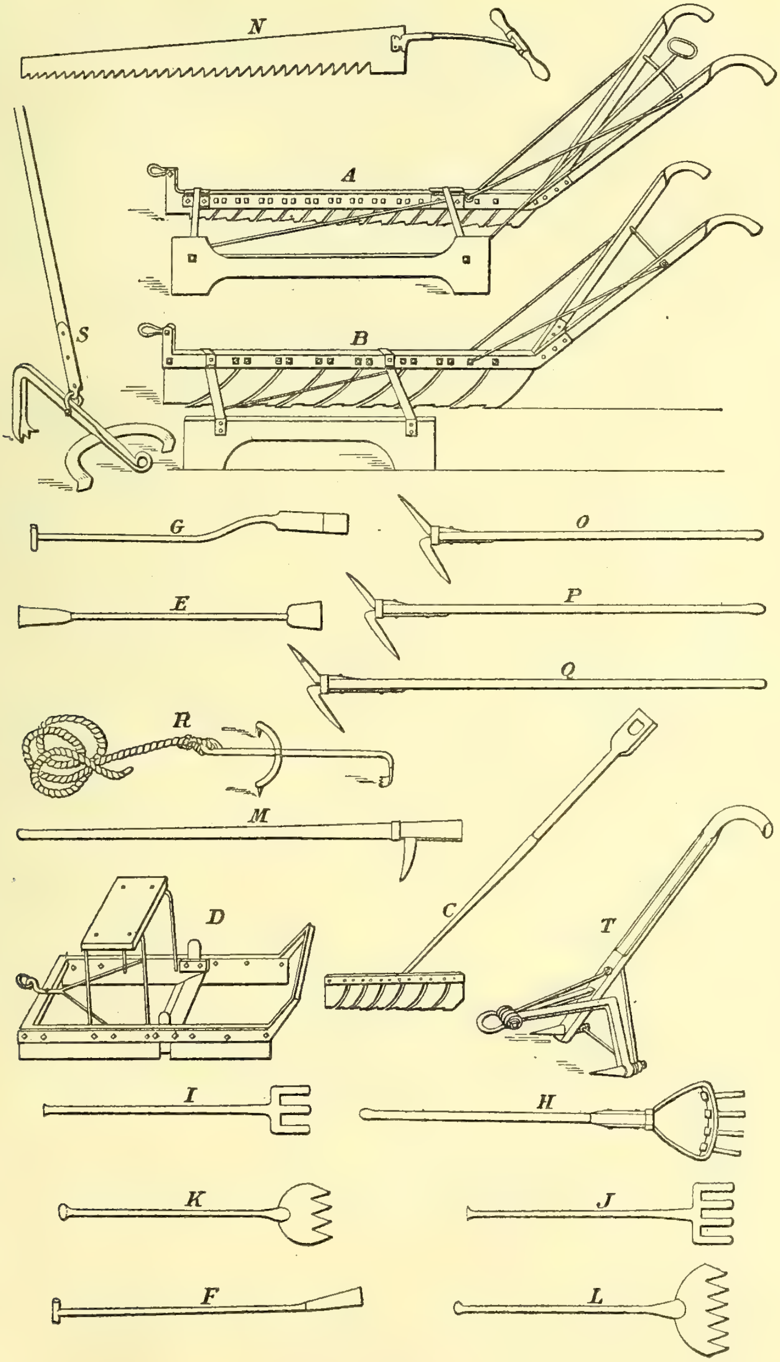
(See Bones; Celluloid; Ivory.)

HOSIERY.—See **KNITTED FABRICS.**

ICE (Fr., *Glace*; Ger., *Eis*).

Ice is too familiar an object to require definition. This article will be divided into two sections, treating (1) of the trade in natural ice, and (2) of the artificial production of ice, and refrigeration generally.

830.



Natural Ice.—Some of the colder countries, as N. America and Scandinavia, have what is called an "ice-harvest" every year. When the ice on the lakes and fjords is about 1 ft. thick, the snow and rough surface-ice are carefully planed off by an ice-plane, drawn by horses. This done, a straight groove is cut along one side of the clean ice-sheet, by means of the hand-plough. Then, by means of the swing guide-marker, a continuous series of similar grooves are marked parallel to the first and equidistant from each other. The large ice-plough is next drawn over these grooves, deepening the cut to 12–14 in. The same operation is repeated at right angles to the first grooves, and the blocks are ready for separation. To prevent the water meantime from entering the grooves, and freezing them up, they are firmly caulked with snow, driven down by the caulking-bar. When the two outside rows have been sawed out, the blocks are lifted upon the adjacent ice, and the remaining rows are separated by breaking-bars. The blocks are then floated to the ice-house, and stored in tiers, carefully covered with pine-shavings.

Fig. 830 shows the principal tools used in the harvesting of natural ice: A, marker, with swing-guide; B, plough, with stationary guide; C, hand-plough; D, snow-plane; E, grooving-bar; F G, striking-under bars; H I J K L, fork splitting-bars; M, channel hook-bar; N, ice-saw; O P Q, ice-hooks; R S T, grapples.

In America, the consumption of ice is truly enormous, being estimated, in the Middle States, at 1600 lb. a year for each individual. The supply is obtained from the rivers and lakes in the interior, the four chief sources being Boston and neighbourhood, the Kennebec region (Maine), Hudson River (New York), and the Upper Schuylkill and Lehigh region (Pennsylvania). The quantity of ice cut on the Hudson River is about 1¼ million tons annually, and on the Kennebec and Penobscot and their tributaries, about 1 million tons. For a short time, we too were dependent upon the American continent for our supplies of natural ice; but the loss and cost in transport rendered the price so high as to be unable to compete with Scandinavian ice, when the latter came into the market, and our imports of ice in 1879 were 166,452 tons, value 139,714*l.*, from Norway, and only 5 tons from all other countries.

Artificial Ice.—Refrigeration, or the artificial production of ice, consists simply in transferring the heat of the water (or other body to be frozen) to some other body. Water at 15½° (60° F.) contains an excess of heat beyond that of an equal weight of ice at 0° (32° F.) amounting to 170·65 heat units for each lb., therefore, to reduce the water from the first temperature to the second will necessitate the abstraction of that amount of heat from it; to reduce 1 ton of water will require the removal of 62,720 heat units, or 2240 lb. × 28 (the difference between 32° and 60° F.). It would still be water. To convert it into ice, it is further necessary to abstract the latent heat, which determines the liquid state of water, amounting to 142·65 heat units for each lb. of water; or, for 1 ton, 2240 lb. × 142·65 = 319,536 heat units, bringing the total to 382,256 heat units. It is thus evident that about five times greater expenditure of power is necessary to transform water at the freezing-point into a solid condition (ice), than is necessary to reduce its temperature from the ordinary point to the freezing-point; and this fact must be borne in mind in the practical application of refrigeration to commercial purposes, where a low temperature will often be as effective as the actual production of ice.

In the use of so-called "freezing-mixtures," the reduction of temperature in the body is due to the absorption of its heat by the process of solution suffered by the salts employed. They are principally as follows:—

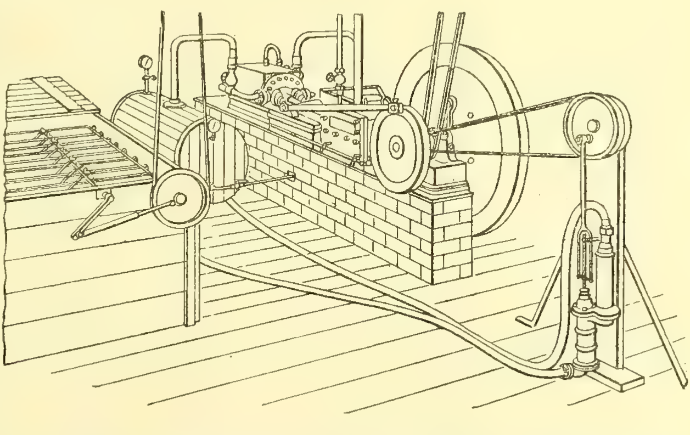
Mixtures.	Thermometer sinks: ° F.	Actual Reduction of Temperature: ° F.
(1) 2 parts snow or pounded ice, 1 part sodium chloride	to −5°	
(2) 5 parts snow or pounded ice, 2 parts sodium chloride, 1 part ammonium chloride	to −12°	
(3) 24 parts snow or pounded ice, 10 parts sodium chloride, 5 parts ammonium chloride, 5 parts potassium nitrate	to −18°	
(4) 12 parts snow or pounded ice, 5 parts sodium chloride, 5 parts ammonium nitrate	to −25°	
(5) 1 part ammonium nitrate, 1 part water	from 40° to 4°	36°
(6) 5 parts ammonium chloride, 5 parts potassium nitrate, 16 parts water	" 50° to 10°	0°
(7) 5 parts ammonium chloride, 5 parts potassium nitrate, 8 parts sodium sulphate, 16 parts water	" 50° to 4°	46°
(8) 5 parts sodium sulphate, 4 parts dilute sulphuric acid	" 50° to 3°	47°
(9) 3 parts sodium nitrate, 2 parts dilute nitric acid	" 50° to −3°	53°
(10) 3 parts snow, 2 parts dilute sulphuric acid	" 32° to −23°	55°
(11) 1 part ammonium nitrate, 1 part sodium carbonate, 1 part water	" 50° to −7°	57°
(12) 8 parts snow, 5 parts hydrochloric acid	" 32° to −27°	59°
(13) 6 parts sodium sulphate, 4 parts ammonium chloride, 2 parts potassium nitrate, 4 parts dilute nitric acid	" 50° to −10°	60°

Mixtures.	Thermometer sinks: ° F.	Actual Reduction of Temperature: ° F.
(14) 9 parts sodium phosphate, 4 parts dilute nitric acid ..	from 50° to −12°	62°
(15) 7 parts snow, 4 parts dilute nitric acid	„ 32° to −30°	62°
(16) 4 parts snow, 5 parts calcium chloride	„ 32° to −40°	72°
(17) 2 parts snow, 3 parts crystallized calcium chloride ..	„ 32° to −50°	82°
(18) 3 parts snow, 4 parts potash	„ 32° to −51°	83°
(19) 6 parts sodium sulphate, 5 parts ammonium nitrate, 4 parts dilute nitric acid	„ 50° to −40°	90°

These freezing-mixtures are very useful for application on a small scale, but are not adapted for commercial operations. In selecting bodies for abstracting and absorbing heat with the object of producing refrigeration on an extensive scale, several points require to be taken into consideration. (1) The first is the amount of latent heat absorbed by 1 lb. of the body in changing its state, being 966·1 heat units for watery vapours, 900 for gaseous ammonia, 364·3 for alcohol vapour, 162·8 for ether vapour. The amount of artificial cold produced will be in inverse ratio: thus the formation of 1 ton of ice will necessitate the vaporization of about 395⅔ lb. of water, 424¾ lb. of liquid ammonia, 1049¼ lb. of alcohol, or 2348 lb. of ether. (2) The next important consideration is the degree of facility with which the bodies are vaporized, and the range of temperature within which the vaporization can be readily accomplished, or, in other words, the boiling-point of the body and the tension of its vapour. It is sought to obtain a body having the former as low as is convenient, combined with the latter also moderately low. Many practical difficulties have been encountered through selecting bodies possessing the former quality, without much regard to the latter. Thus, at a temperature of 24° (75° F.), which is often exceeded in town waters in warm countries, the tension of liquid ammonia will be 150–160 lb. a sq. in.; chloride of methyl, about 80 lb.; methylic ether, 78 lb.; sulphur dioxide (sulphurous anhydride or oxide), 60 lb. These immense pressures necessitate extreme care in the construction of the apparatus, thereby enhancing the cost; and the difficulty of keeping the joints tight often occasions loss of material and reduced production. (3) Equally necessary to be taken into consideration, is the condensation of the vaporized body, in order that it may be used over again. This condensation is effected by means of a supply of cold water. In some industries, and in certain localities, the scale of consumption of water for this purpose is such as to altogether preclude the use of certain machines. (4) The chemical properties of the substances employed must be studied in relation to their action upon the metal or other material with which they will come into contact. Having said so much concerning the general principles and conditions involved in the artificial production of a low temperature, or ice itself, some space may now be devoted to a description of the principal machines devised with this object.

An ether ice-machine, made by Duvallon and Lloyd, of Birmingham, is shown in Fig. 831. It consists of an engine and air-pump, combined on the same bed-plate; a refrigerator; an ether-condenser; a circulating-pump; and one or more ice-boxes, according to the quantity of ice required. In the illustration, the air-pump is 9¼ in. in diameter, driven direct by a steam-engine, with 7½-in. cylinders, the stroke being 21 in. The two cylinders are arranged in line, the two piston-rods being cottered to the cross-head. The guides consist of hollow angle-pieces, working on the corners of the square bars. The air-pump is double-acting. The connecting-rods, one at each side of the cylinder, work on crank-pins, inserted in discs keyed upon the main shaft, one of these discs being of considerable weight, so as to act as a fly-wheel. In the centre of the main shaft, is a pulley for driving overhead-shafting, from

831.



which the circulating-pump and the agitator derive their motion. The two inlet passages of the air-pump, one at each end, are connected by a copper pipe, from which branches another copper pipe, placing them in communication with the refrigerator. This is a cylindrical vessel, similar in construction to a multitubular boiler, covered with felt, and lagged with wood; the tubes are made of copper, and riveted to brass end-plates. On the other side of the air-pump, the two outlet valves, connected in the same manner as the inlet valves, are placed in communication with the ether-condenser, which is similar in construction to the refrigerator, but is of rectangular section, and has no copper shell. The tubes communicate at each end with metallic chambers, one of them acting as a receptacle for the air which finds its way into the condenser. The whole is immersed in a tank of wood, or of galvanized iron, through which a constant stream of water is made to pass, for cooling and condensing the ether vapour. A vacuum of about 25¼ in. is maintained by the air-pump in the refrigerator, vaporizing the ether at a low temperature. The absorption of heat due to this operation lowers the temperature of the strong brine, made to circulate, by means of the pump provided for that purpose, through the tubes and the ice-box. The latter is a tank of red deal, varnished inside, with partitions having holes bored in them for allowing the brine to circulate slowly. Between the partitions, are suspended zinc moulds of rhombic form, varying in width according to the shape of the blocks of ice required, and filled with pure water. The capacities and prices of this machine vary approximately from 120*l.* to make 3 cwt. of ice per 24 hours in England, to 2800*l.* to make 200 cwt. in the same time.

Another form of ether-machine, invented by A. Mühl, of San Antonio, Texas, is shown in Figs. 832 and 833. The pumps A are connected with the driving-shaft, as shown; the condenser B contains a worm, which communicates, through the pipe on the outside, with the reservoir C below; D E F are freezing-vessels of various forms. Each pump, as its piston rises, draws in from the freezing-vessels the ether which has been vaporized by the heat abstracted from the water or other liquids contained in them; as its piston descends, the vapour of the ether is forced into the worm of the condenser, and thence into the reservoir C, which it reaches in a liquid state; it then passes into the freezing-vessels, where it is reconverted into vapour, and flows thence back into the pumps. The pumps have their induction pipes provided with suction-valves (see A, Fig. 833), and their eduction pipes with exhaust-valves.

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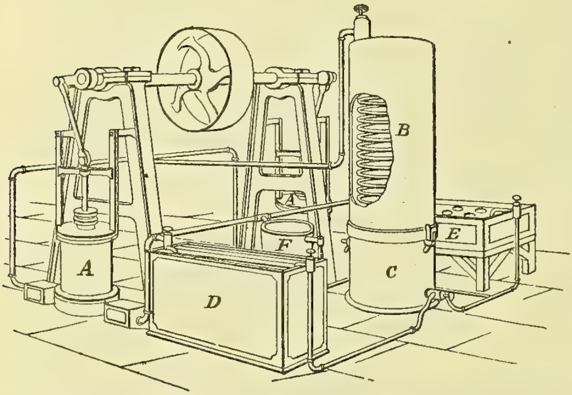

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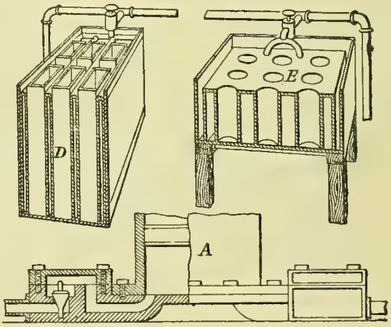


The usual practice of making the worm, which is the principal agent by which the vapour is reduced to a liquid, of pipe of uniform diameter throughout is objectionable, for the following reasons: If a small pipe is used, it is difficult to force the vapour through fast enough, and an unnecessary amount of power is consumed without effect; on the other hand, if the pipe is of the customary size (1–2 in. in diameter), only the layer of vapour immediately in contact, or nearly so, with its sides, is condensed, and the remaining uncondensed portion is discharged into the reservoir, there to be condensed at the expense of considerable power; or is caused to enter the freezing-vessel before condensation is effected, thereby defeating the object intended. To obviate these difficulties, the worm is composed of pipes of several different sizes. Several coils of large pipe, say 1½ in. in diameter, are used at the point of entry, and are followed by coils of 1 in., ½ in., and ¼ in., by the last of which the exit is made. By this means, no resistance is offered to the passage of the vapour at its commencement, and all parts of its body are afterwards brought sufficiently near the sides of the pipe to ensure its condensation before the reservoir is entered. Thus power is saved, and the full effect of the freezing-apparatus is developed.

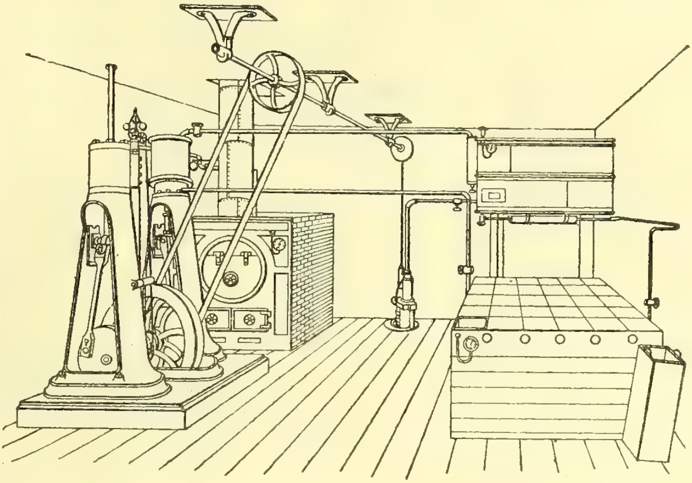
The condenser B is kept full of running water while the machine is in operation, and the action of the latter is regulated and kept under complete control by the aid of valves and stop-cocks.

The freezing-vessel shown at D contains cans, in which blocks of ice are produced; these cans stand between hollow metallic partitions, through which the freezer passes. The vessel E, seen also in Fig. 833, is provided with receptacles for holding bottles, or other small vessels, around which the ether circulates. That at F is of conical form, and has double walls for the passage of the ether.

Siddeley and Mackay's refrigerating-machine, which has been already described under Carbolic Acid (p. 673), also works with ether.

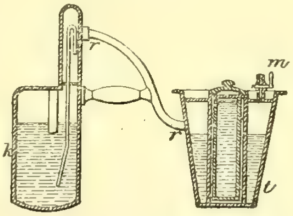
An ice-making apparatus, in which ammonia is the medium used, constructed by the Boyle Ice Machine Co., of Chicago, Illinois, is shown in Fig. 834. On the left, are a steam-boiler and a combined engine and ammonia-pump; in the centre, a pump for water supply for the gas condenser; and on the right, a freezing-tank. The ammonia-pump is used for compressing the ammonia gas, which is liquefied in the condenser, and expanded in a freezing-tank seen on the right, in which the cold is produced. This freezing-tank is provided with coils of iron pipe, in which the gas evaporates; they are placed at regular spaces apart, determined by the thickness of the ice required. Between the coils, are placed moulds or cans, containing the water to be frozen; and the space about both moulds and coils is filled with strong brine. The pump being put in motion, a valve leading from the condenser to the evaporator-coils is opened, and the gas flows into the evaporator-coils. Meeting there with the heat in the salt water to be cooled, it expands very rapidly, taking up the heat which is in the brine, which, in turn, extracts the heat from the water in the moulds. The expanded gas is aspirated by the pump, and forced over into the condenser, where the heat is taken from it by a stream of water continually flowing over it, and where, under the pressure of the pump, it is reliquefied, and returns to be again expanded in the evaporator-coils. This process is continued until the water is frozen, when the mould is lifted from its place in the freezing-tank, and immersed in warmer water, which loosens the ice from the mould; the latter, being refilled with water, is returned to the freezing-tank.

834.



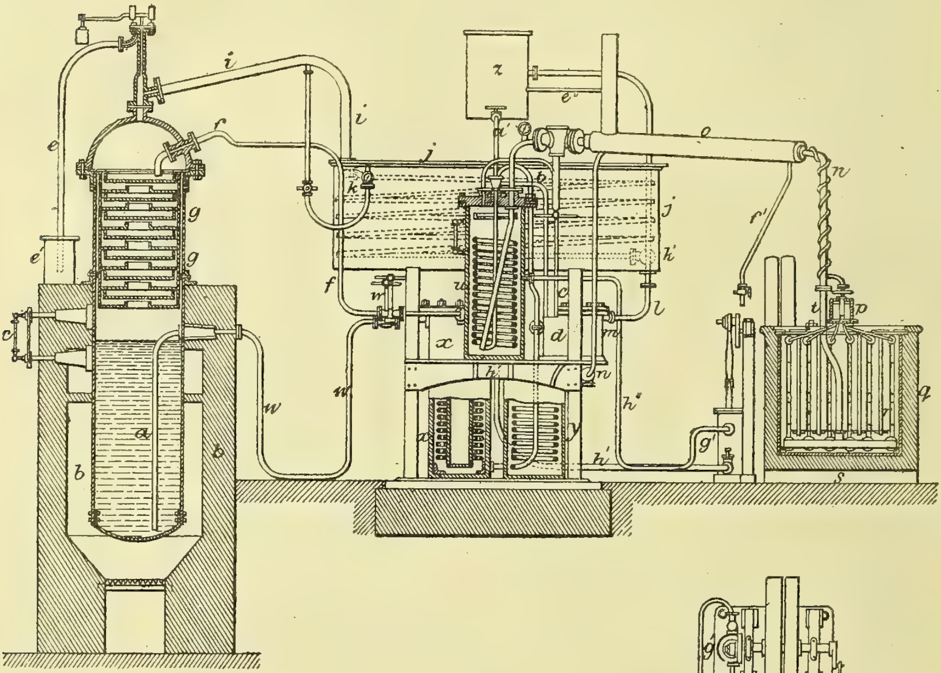
Carré's intermittent portable apparatus, in which ammonia is employed, is shown in Fig. 835. A boiler *k* containing the ammonia is connected by the pipe *r* with the refrigerator *t*, into the well of which are put vessels *z* filled with water to be frozen. The boiler *k* is placed over a portable furnace, and the apparatus is purged of air, which is driven by the evolved gas out at the stop-cock *m*. This being closed, and the refrigerator immersed in a tank of cool water, the temperature of the liquid ammonia is raised to 110°–115° (230°–240° F.), at which heat the ammonia is expelled, and condensed in a liquid form in the refrigerator *t*. The boiler being now removed from the furnace, and placed in the water-bath, the temperature of the water in it will fall, and the power of the water to dissolve ammonia will be restored. The gas will be rapidly re-dissolved, reducing the pressure, as the liquid ammonia will evaporate with corresponding rapidity, drawing for its latent heat upon the sensible heat of the water to be frozen. The result will be the complete evaporation of the liquefied ammonia, and the restoration of an aqueous solution in the boiler, of the original strength. Between the ice-pan and the well, is a body of alcohol, which will not freeze, but will act as a conductor. During the refrigeration, the vessel *t* has a non-conducting envelope.

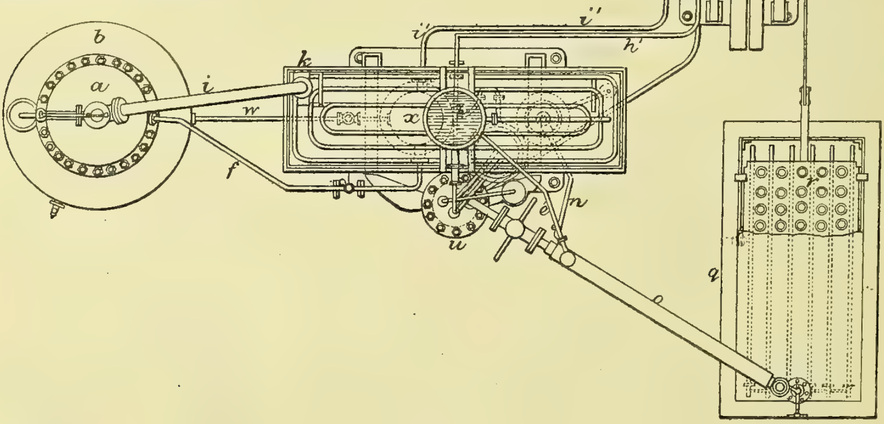
835.



Carré's continuous process, shown in Figs. 836 and 837, also depends for its efficacy upon the evaporation of liquid ammonia. The boiler *a* is exposed to the heat of the furnace *b*; *c* is an indicator to show the level of the liquid; *i* is a tube conducting gas to the liquefier *j*; the vertical pipe above the branch *i* leads to a safety-valve; and any escaping gas passes by pipe *c* to the water-tank *e'*, where it is absorbed; *f* is a tube which brings back to the boiler saturated solution of ammonia from the absorbing-apparatus *u*; this solution passes downward, trickling through the perforated trays *g*, while the ascending gas rises in a sinuous course, alternately around the edge of one tray and through a central hole in the next, and so on. This condenses and carries back the watery vapour which accompanies the gas. The latter passes by tube *i* to the liquefier *j*, through a box *k*, and a series of zigzag and spiral tubes in a bath of cold water, constantly renewed from reservoir *z*, which also supplies other parts of the apparatus. The tubes terminate in another box *k'*, and the ammonia is by this time in a liquid state, under a pressure of 10 atmos., which is constantly maintained in the boiler. In the liquid state, the ammonia passes by the pipe *l* to the efflux regulator *m*, which is the dividing barrier between the part of the machine in which a regular pressure of 10 atmos. is maintained, and the following part where the pressure does not exceed $1\frac{1}{2}$ atmos. The regulating device is a floating cup, which opens or closes a hole of influx. The liquid passes from the regulator *m* by pipe *n* to the distributor *p*, the pipe *n* being wound spirally around the tube *t*, through which the vaporized ammonia is returning from the refrigerator *q*; the vapours serve to reduce the temperature of the liquid in *n* before it reaches the refrigerator.

836.





837.

The refrigerator itself consists of a number of zigzag or spiral tubes, immersed in a tank constructed of non-conducting substances. Each one of the zigzags receives an equal supply of liquid ammonia from the distributor. The small tubes conveying this supply are shown at *p*. The vessels *r* to be refrigerated are sustained on a carriage, which is slid to and fro by the same power that works the pump *g'*, by which the re-saturated solution of ammonia is returned to the boiler. The space in the tank surrounding the zigzags and the water-vessels is filled with an uncongealable liquid, such as alcohol, or a solution of chloride of calcium. The ammonia in the zigzags *q* discharges in a vaporized form into the collector *s*, and passes through the tube *t* to the cylinder *u*, where it extends nearly to the bottom of the vessel, and there discharges the gas into the water which has been brought from the bottom of the boiler *a*, and partially fills the cylinder *u*. From this water, the ammonia has been nearly exhausted, and it therefore greedily absorbs the gas ejected into it by pipe *t*. On the left of vessel *u*, is a water-level indicator. Within the vessel *v*, is a worm which receives water by the pipe *a'* from the elevated reservoir *z*; after passing to the bottom of the spiral, the pipe curves upward, and then (marked *b*) descends nearly to the bottom of the vessel *y*, where it discharges.

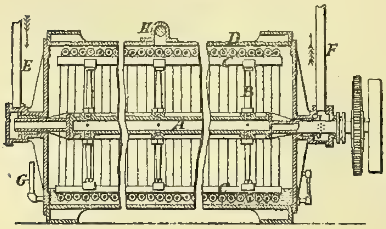
The water from the boiler *a* passes by pipes *w* to the coolers *x y*, before reaching the vessel *u*, where it re-absorbs ammonia. Between the boiler *a* and the vessel *u*, the water is cooled so as to fit it for absorbing gas more freely. The pressure in the boiler is sufficient to expel it when the stop-cock *w* is opened. The vessel *x* is formed of two concentric cylinders, between which are two spiral tubes, formed of the pipe *w* continued, and these spirals are immersed in a liquid which fills the annular space between the cylinders, and is the reconstituted ammoniacal solution on its way from the absorber *u* to the boiler *a*. From *x*, the water in the spiral is conveyed in the pipe *w*, still continued in a single spiral ascending in the vessel *y*, and continued farther in a pipe *w*, alongside of the absorber *u*, where it discharges into a sieve *v*, and from which it descends in a shower. The exhausted solution from the boiler flows freely by the pipe *w* to the absorber *u*, passing the coolers *x y*, as described; but it requires some power to force the reconstituted solution back from the absorber *u* through the pipe *f* to the boiler. This power is a pump *g'*, driven by a steam-engine or other motor, taking the saturated solution from the absorber by pipe *h'*, and discharging it by pipe *i'* into the vessel *x*, whence it passes by pipe *f* to the dome above the boiler. Gas finding its way into the pump is discharged into the upper part of *n*. A pipe *e''* leads to the enveloping-tube *o*, whence water is conducted by *f'* for the use of the ice-vessels *r*. As the water passes through *o*, it is cooled by the ascending vapours of ammonia. In starting the machine, it is first blown through to expel the air. The air escaping from the vessel *u* passes by the pipe *c* to the purger *d*, and beneath the surface of the water therein, which retains any escaping ammonia.

Holden's (of Philadelphia) machine is adapted to the use of almost any volatile liquid, whether ether, ammonia, carbon bisulphide, &c. The refrigerator-cylinder, Fig. 838, is covered with a non-conducting substance. It is journalled on a longitudinal shaft A, provided with radial arms B, which carry upon their outer ends longitudinally arranged ribs C. Around these ribs, and near the inner periphery of the cylinder, is wound a continuous coil-pipe D, in which circulates strongly saturated brine, or other non-congealable liquid, which is received from a convenient cistern or tank. A coil of pipe extends the entire length of the cylinder, and, at each end, communicates with the hollow ends of the shaft A, and through this hollow with the supply-pipe E, and the exit-pipe F, so that a continuous circulation of the non-congealable liquid may be kept up in the coil. Inside this cylinder, the volatile liquid is placed. It is introduced through a pipe G, and is maintained at such a level as to immerse the bottom portion of the coil of pipes, which level may be regulated by means of a glass gauge upon the outside. As the coil of pipes is revolved, the coil passes to the upper portion of the cylinder with its surface moistened by the volatile liquid, which it carries up from adhesive attraction; and as the cylinder is exhausted of its gaseous contents through the pipe H by means of pumps, the evaporation of the liquid upon the surface of the coil rapidly takes place to supply the partial vacuum, and a corresponding reduction of the temperature of the pipes and its contained vehicle of non-congealable liquid takes place. To guard against leakage, which would prevent the best action of the pump in effecting evaporation, the ends of the shaft A are provided with stuffing-boxes, while the outer parts of the bearings are enlarged to form water-boxes, which are filled with the non-congealable liquid, and these, together with the stuffing-boxes, effectually seal the bearings against all leakage of air in the interior.

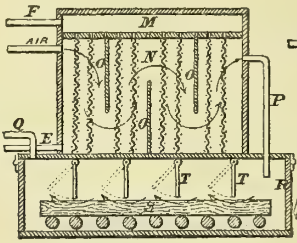
As the gas is exhausted from the cylinder, it passes to the pumps previously referred to, thence to a condenser, and thence through a pipe (as liquid) to a receiver. The cooled non-congealable liquid passes into the case M, Fig. 839, through the pipe F, and thence back to the coil in the cylinder through the pipe E. The circulation of liquid is effected through a circulating-pump, which is operated by the engine which works the large pumps, the refrigerator-coil, and a rotary blower for circulating air in the congealing-case.

The two large pumps detailed in Fig. 840, communicate with pipe H from the cylinder, through inwardly-opening check-valves I, located in the branches of the pipe. These pipes are also provided with a gravity cup-shaped valve J, which is of greater diameter than the piston-cylinder, and plays between the cylinder-head and the flange of the body of the cylinder, upon which it is seated, being guided in its movement by ribs in the enlarged cavity of the cylinder-head. On the descent of the piston, the gas is drawn through the pipe H, the check-valves I are opened, and the pump-cylinder is filled. But when the piston rises, the check-valves are closed, and the compressed gases above the piston lift the valve J, and allow the gas to pass out into the pipe, and thence to the condenser through K. As, however, the gases contained in the portion of the pipe between the pump-cylinder and the check are compressed, but not forced out, if the piston should descend with this pressure of gas contained here, the gas would expand, and, by partially filling the chamber, prevent the perfect exhaustion of the gas-cylinder. To provide for this, the piston in its upward stroke passes the orifices of pipe H, so that the compressed charge of gas is held in the confined space, and is liberated beneath the piston, and, upon its descent, is driven out through the valve L at the bottom into a pipe that communicates with K. The face of the piston, in rising, strikes against the bottom of the cup-valve and lifts it, and, upon the reverse stroke, the valve seats itself upon the flange of the cylinder, while the plain ground face of the piston departs from the plain ground bottom of the valve, producing as nearly a perfect vacuum as it is possible to attain in a pump, there being practically no cushion of gas left between the valve and piston.

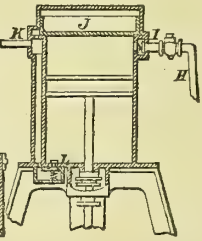
838.



839.



840.

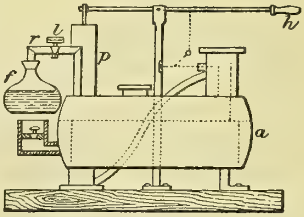


As the gas is delivered to the condenser, it is made to traverse coils, and is cooled by the circulation of water of the normal temperature which passes through the condenser. As the gas is liquefied, it passes into the receiver, where it accumulates, and is fed from time to time back into the refrigerator-cylinder. As the non-congealable liquid in the coil of the refrigerator circulates, it passes out through the pipe F to the distributing-pan M, where its temperature is to be transferred to the air circulating in the subjacent case N. The upper case is provided with a distributing-pan, into which the cooled liquid is admitted. The bottom of the pan has perforations, which are arranged in rows immediately above a series of vertical partitions of wire gauze, between which are arranged the vertical baffle-plates. As the cooled liquid drops through the perforations in the pan, it falls upon the wire partitions, and being retarded in its descent, trickles slowly down, while the current of air driven through the case by the blower is made to penetrate all parts by reason of the baffle-plates, and in so doing, takes on the temperature of the non-congealable liquid, which is below the freezing-point of water, passes into the congealing-case at and through pipe P, then traverses the pans in the congealing-case to freeze the water therein contained, and after having done its duty, passes up through the blower and pipe Q, to be again reduced in temperature. The congealing-case has doors R at each end, and is provided with supporting-rollers, upon which the pans S are fed in at one end and removed at the other.

This apparatus was first designed solely for reducing the temperature of liquids, such as beer when the liquid to be cooled is allowed to trickle down over the refrigerating-coil. It has been widely adopted in American breweries. For the production of ice, additional plant is necessary, consisting of a large tank, and suitable receptacles for the water. A novelty in Holden's arrangement is that the water-holding vessels are introduced at one end of the tank and removed at the other, passing through a progressively increasing degree of cold.

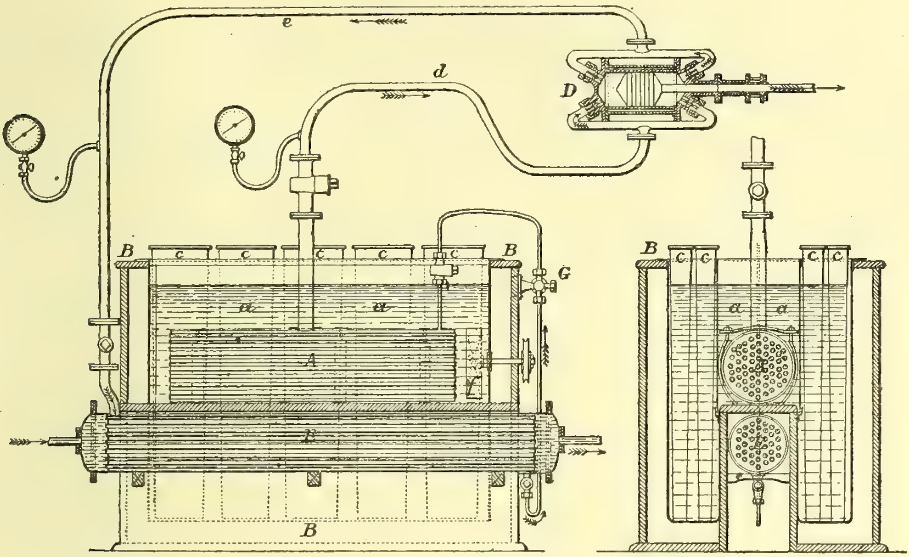
Sulphuric acid is employed in E. Carré's apparatus, Fig. 841. It consists of a large vessel *a*, for holding the concentrated sulphuric acid; an air-pump *p*, with tube-connections *r* adapted to the mouths of the decanters *f*; and a mechanism by which the lever *h* of the air-pump keeps the acid in continual motion; *l* is a stop-cock. This apparatus is useful for cooling drinks.

841.



One of the most important machines for producing a low temperature is that introduced by Raoul Pictet, of Paris, in which anhydrous sulphurous acid (SO_2), also called sulphur dioxide, sulphurous acid, sulphurous oxide, or sulphurous anhydride, is employed. Its arrangement is shown in Figs. 842 and 843. The valves of the compression-pump D are so disposed that at one stroke the sulphurous oxide is aspirated through the tube *d*, and, in return, is compressed through the tube *e*. The tube *d* connects with the refrigerator A, placed in the sheet-iron vat B, lined with non-conducting material; the tube *e*, with the conductor E. The oxide is introduced at the plug-cock G, and is drawn by the pump in the direction of the arrow into the copper-tubular refrigerator

842. 843.



A, the liquid filling the space between the tubes. Here takes place vaporization, with the consequent production of intense cold, and the temperature of the non-congealable mixture of glycerine and water surrounding the refrigerator is so far reduced that water placed in the metallic vessels *c*, immersed in the tank, rapidly becomes frozen. The propeller-wheel *f* sends a current of the glycerine solution through the tubes, and thus hastens the refrigeration. The vapour of the oxide is drawn out of the refrigerator by the pump, and forced into the space between the tubes of the condenser E. Through these tubes, a stream of cold water is constantly forced; this determines the condensation of the vapours, and the re-liquefied oxide passes into the admission-pipe, and enters again into circulation. A saturated solution of chloride of magnesium gives better results than the glycerine mixture. The tension of the oxide vapour varies from about 14·7–13 lb; on the return stroke, the gas is compressed to $\frac{1}{4}$–$\frac{1}{5}$ its original volume, having its temperature raised to 93° (200° F.). The cold water current reduced this temperature to about 16° (61° F.) at the outlet; and under a pressure of 3–3$\frac{1}{2}$ atmos., the gas resumes a liquid state. It is claimed that 1 lb. of acid produces nearly 1 lb. of ice; and that with a consumption of 22$\frac{1}{2}$ tons of coal, 250 tons of ice can be made every 24 hours. The cost is said not to exceed 1*c*. a kilo. (say $\frac{1}{2}$*d*. a lb.). The system is largely adopted in skating-rinks, breweries, &c.

The production of a low temperature by the alternate compression and expansion of air is perhaps best accomplished by the Bell and Coleman apparatus, which has been described in the article on Food Preservation, its primary application being for preserving fresh meat on long voyages.

The "binary absorption" system of Tessié du Mothay and A. I. Rossi is the most recent development of the science of producing artificial cold. Experiments on ethers indicated that those formed by the acids, as well as their alcoholic radicals, possess the property of absorbing sulphurous anhydride (sulphur dioxide), some of them to the extent of 300 times their volume of gas in certain conditions, ordinary ether standing first. Upon this fact, the new system is founded. The liquid employed is ethylo-sulphurous dioxide, obtained from ordinary ether by saturating with sulphurous oxide gas. This liquid, at a temperature of 15°–18° (60°–65° F.), has no pressure, and can be readily kept in glass bottles at 27°–32° (80°–90° F.); its tension is only 2–5 lb. Thus a machine charged with it, when stopped, will show no pressure on the gauges, and even a vacuum at rest, if the temperature is low; while with other liquids, even the stoppage of the machine does not prevent the pressure of the vapours inside soon reaching its point of equilibrium with the temperature outside, and even at as low a temperature as 0° (32° F.) sulphur dioxide (sulphurous oxide) alone, as used in the Pictet machine, has still 15 lb. a sq. in. of pressure, exerting a constant and increasing pressure on the vessels containing it, and, in case of a small leak starting, causing the entire loss of the charge. What is said here of sulphurous oxide applies with still more force to liquid ammonia, methyl chloride, and methylic ether.

Such a binary liquid as that just mentioned, when evaporated under a vacuum, is resolved into its two constituents, the mixed vapours entering the pump together; then, under a small compression, ether liquefies first, a few lb. pressure being sufficient for it, even with such waters as are met with in tropical climates. The ether thus liquefied absorbs in the condenser the vapours of sulphurous oxide, reconstituting the "binary liquid," and thereby avoiding the excess of mechanical compression, which would otherwise have been necessary to effect this liquefaction of the oxide. Thus for the work of compression of the pump, is substituted a power of chemical affinity, and absorption of the less volatile absorbent for the vapours of the more volatile. With the advantage of the low pressure of the ether, is combined the advantage of the intensity of cold produced by the volatilization of the sulphurous oxide, avoiding its drawbacks. In presence of water and the ether, the sulphurous oxide is transformed, not into sulphuric acid, as before, but into "sulphorinic" acid, the action of which acid upon metals is insignificant, if not absolutely nil. The sulphurous acid being an extinctor relieves the ether of one of the drawbacks to its use, and acting as self-lubricant, renders the greasing of the working parts unnecessary. In a machine making 6 tons of ice daily, the pressures in the condenser in normal and regular working have been 14–15 lb., descending to 10–11 lb. under most favourable conditions, and reaching 20–23 lb. under least favourable conditions. The water used for condensation has been but $\frac{1}{4}$–$\frac{1}{3}$ of that needed by a Pictet machine of the same capacity. The smallness of pressure required renders the machine much simpler, ordinary valves, &c., sufficing. The New York Ice Machine Co. are working very successfully with the system in the United States.

Bibliography.—B. H. Paul, 'Artificial Freezing and Refrigeration' (Jour. Soc. Arts, vol. xvii., No. 839, London: 1868); M. Ledoux, 'Ice-making Machines' (New York: 1879).

INDIARUBBER MANUFACTURES.

Under the term "indiarubber manufactures," will be included a description of the manufacture of those articles in which indiarubber or caoutchouc, guttapercha, and some allied exudations are largely employed. For an account of the raw materials, the reader is referred to the article on Resinous Substances.

The name "caoutchouc" in England is generally confined to the pure hydrocarbon forming the greater portion of ordinary indiarubber; its composition, according to Faraday, is represented by the formula C_7H_8. The chemical and physical properties of this substance extend more or less to the commercial kinds of rubber, and, in proportion as a sample of rubber approaches the qualities of pure caoutchouc, its commercial value increases. The internal portions of best Pará "bottle" rubber, when dried in the dark, are sufficiently pure for any practical examination of the substance. The amount of the pure principle contained in any given sample may be ascertained by dissolving in highly rectified ether, and precipitating with alcohol, which should be repeated for a high purification. Ether containing alcohol, does not dissolve caoutchouc at all. Caoutchouc readily oxidizes on exposure to the air, becoming brown on the surface, which is blackened and rendered rotten by extreme oxidation. This coloration is removed by alcohol or alcoholized ether. Long digestion of masticated rubber, in alcohol, renders it quite colourless; but it becomes sticky, and, on exposure to the air, rapidly darkens in colour. Caoutchouc is soluble in ether, chloroform, carbon bisulphide, coal-tar naphtha, benzol, turpentine, and in almost any liquid hydrocarbon; incorporated with solid hydrocarbons, as naphthalene, or paraffin, it behaves under the influence of heat in the same way as a true solution. It is insoluble in water, alcohol, and acid and alkaline solutions; but is rapidly acted upon by strong mineral acids, especially when heated, and by chlorine, bromine, and iodine in the cold. Heated above 4° (40° F.), it is soft and elastic, and remains the same at 100° (212° F.); below 4° (40° F.), it is hard and inelastic, but not brittle; when heated to 115° (239° F.), it softens, and is decomposed into a sticky, tarry mass by standing for a few days; congelation prevents this only while it lasts: heat accelerates the change. In this condition, however, it may be vulcanized. By destructive distillation, it yields a series of liquid hydrocarbons, which have been employed as solvents for caoutchouc, as lubricators, &c. They do not possess any particular interest, although a study of them might furnish very important information as to the synthetic production of this or similar hydrocarbons; the substances known as "artificial rubber," &c., are widely different in composition from caoutchouc. Contact with oily or fatty substances induces the decomposition of caoutchouc. Its sp. gr. is 0·925–0·950. On incineration, it should yield only an insignificant amount of ash. In commerce, the manufactured article is frequently called "rubber" or "indiarubber"; when cured or vulcanized, it is called "vulcanized rubber," if soft; and "vulcanite" or "ebonite," when cured to a hard or horny condition. Raw indiarubber as met with in the markets is technically called "gum." The best descriptions, in order of purity, are the Brazilian, Central American, Asiatic, and African. There are many applications, where the inferior kinds, irrespective of their being cheaper, are better adapted than the finer descriptions. Pará rubber yields a hard and strong material when vulcanized, but is always contaminated with the taste and smell of the raw product. Negrohead has a still more unpleasant taste and smell when vulcanized, and is softer.

The preliminary treatment of all kinds of rubber is much the same as regards sorting, washing, and drying; there is, however, a great difference in carrying out the details of these processes, according to the nature or condition of the rubber, some descriptions having to be cautiously heated and dried, whilst others are much more easily manipulated. In selecting raw rubber, preference should be given to packages made up of small masses, or thin pieces, and to those samples which, when cut and squeezed, emit little or no moisture; bark and chips are more abundant in the drier kinds.

Washing and Drying.—The first part of the washing process consists in throwing the raw article into large iron tanks, containing water, sometimes heated by injected steam for a few hours, so as to soften the rubber, and facilitate its cutting up before passing through the washing-machines or rollers. This preliminary boiling serves another purpose: as indiarubber floats easily in water, any portions containing clay, sand, iron, or other heavy matters, sink to the bottom, and are at once detected. It is a common thing to find, instead of these heavier matters, rags, nuts, leaves, and wood concealed in the mass; these portions are not washed with the other, but are kept by themselves, as they require more careful cleansing. The adhering dirt should be scrubbed off, if necessary. The softer kinds of rubber must be treated with cold water, and not boiled.

When removed from the tank, the masses of rubber are cut open with a large knife, if they can be sufficiently examined with one incision, which is the case with those rubbers which are met with in smaller masses; if in large bulky masses, as the Pará and negrohead, and those which become massed by agglutination, it is either cut up by a revolving circular knife, or by an ordinary long-bladed knife. A circular knife is the most expeditious, but is, of course, more dangerous in case of stones being concealed in the rubber. Whichever method is adopted, this cutting up is either performed by the foreman of the washing-shop, or under his immediate inspection, for it not unfrequently happens that a classification is necessary, even with a package of the very best description. It is then passed to the washing-rollers, or washing-machines.

The washing-machine consists essentially of two grooved or corrugated iron rollers, working in journals, and adjustable by means of a screw, working through the front part of the iron framework. Each roller has a strong pinion keyed to one end, and the pair are worked by a strong toothed-wheel, attached to a shaft, which drives several machines. The rollers revolve in opposite directions, and thus drag the rubber through, while a jet of cold water—hot is sometimes necessary—falls upon it, preventing heating from friction, and dissolving out the soluble matters, as gum, sugar, and salts, existing in the natural juices of the plant. Under the machine, is a wooden box, or frame, with a perforated zinc bottom, to let off the water, and prevent the escape of small fragments of rubber.

The speed at which these machines are driven is not a matter of much importance. Sometimes two speeds are employed, generally obtained by working two sets of machines from separate shafting and gearing, and better by having rollers of larger diameter. By giving extra strength to the machine, so as to use larger and longer rollers, labour is economized. The rollers should not exceed 12–18 in. in length; for very fine washing, 9–10 in. will suffice, as they are liable to open out by springing.

The rubber is first passed through a few times with the rollers tolerably wide apart, and as the pieces of wood, bark, &c., are washed out, the rollers are gradually closed, or the rubber is finished off in another machine, with finer rollers set closely. With careful washing, it is almost possible to bring the lower descriptions of S. American, Bornean, and a few others, to a degree of cleanliness equal to that of Pará rubber. Formerly, washing-rollers were enclosed in an iron box or case; now, a wooden hood surrounds the machine, when treating such rubbers as are liable to fly about.

A form of washing-machine which has become almost obsolete may be referred to, as it is especially useful for washing up short or crumbled rubber. It consists of a fluted spindle or axis, with rough teeth, revolving in a strong iron box; the rubber is supplied through an aperture in the top, and is removed by opening the front, which works on a strong bolt as a hinge. This rubber is dried on canvas trays, or strewn on a clean floor.

The ordinary washed rubber comes away from the machines in long sheets, with rough surfaces, and is dried by being hung up for some days in drying-rooms, heated to about 32° (90° F.) by steam-pipes. The influence of direct sunlight on the rubber is prevented by painting the windows white or yellow. Some rubbers cannot be obtained in sheets like this, and are too soft for hanging up; these are dried on the floors. The rubber must not come into contact with the steam-pipes; when thoroughly dried, it is taken down, and stacked away on shelves, in a dry and moderately warm store-room, for seasoning, or for immediate use. Washed rubber improves by stacking, and for insulating purposes, ebonite, and the finer classes of goods, it is preferable.

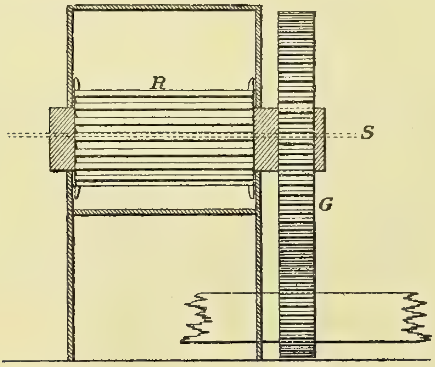
There are great differences in the degree of loss of moisture and impurities even from the same description of rubber; thus, old Pará rubber will suffer a loss of 7–12 per cent., whilst new or green rubber will frequently lose 15 per cent., or even more. Negrohead of good quality may be taken as losing 20–25 per cent.; 15 per cent. was formerly a fair figure, but the practice now is to pack this rubber in very large masses, and frequently to empty into it non-inspissated juice, so that it reaches the English markets quite saturated.

The peculiarities of the different sorts of washed rubber are not easily described, although they are very evident to any experienced person. Washed Pará, negrohead, Ceará, Borneo, Rangoon, and Penang, are the most important. Washed Pará has the peculiar odour of the raw rubber, and, on drying, takes a dark-brownish colour; negrohead has a strong, rather offensive smell, and, as met with in commerce, is generally of a blackish colour; Ceará has a rich light-brownish colour; Borneo is generally black; Rangoon and Penang have a reddish tint when washed and dried.

Masticating.—This process is necessary only for the production of sheet-rubber, slabs or blocks; as it does not destroy the strength of the rubber, it frequently forms a preliminary treatment, when extra grinding would destroy the firmness. Pigmented masticated rubber is sometimes required. There are several ways of obtaining this; (1) by incorporating the pigment roughly with the whole of the rubber, or only a portion of it; (2) by mixing in the "grinders" or mixing-rolls, and finishing off the batch in the masticator; (3) by dusting the pigments on the rubber as it is put into the masticator, which may cause a little loss; (4) a useful plan in many cases is to mix the pigment with a little of the rubber by grinding, and to run it out as a rough sheet, which is cut up, and masticated with the remainder of the rubber. Since the object of the process is not to weaken the rubber, it is evident that the incorporation of the pigments ought not to protract the process more than can be helped. The heat generated in masticating, even when the machine is not heated by steam, renders it almost impossible to incorporate some pigments, as sulphur and red-lead, in this way. Very small proportions of dry pigment can be added at a time in the masticator; consequently, to produce heavily pigmented masticated rubber, an excess of pigment is first ground in by the grinders, and a proportion of this product is passed with pure rubber through the masticator. A great deal of experience is necessary for the production of good cut sheet; the speed at which the masticator is driven is one of the most important conditions for the production of a block from which can be cut sheets, that will not be curly, and will yet be sufficiently worked not to buckle when heated, nor be rendered soft.

Sometimes, especially in cold weather, the rubber is slightly heated on a steam-chest, before being put into the masticator; but more frequently the axis of the machine is made hollow, so as to admit of its being warmed by passing steam through. If a masticator has been standing for some time, and become a little rusty, it is best cleaned by passing through a batch of some rough compound containing rag fibre. When newly set up, a little grinding takes place in the bearings, and it is important that the metal so detached should not become incorporated with the rubber. This renders it necessary to work the machine for a few days on some unimportant compound.

844.



845.

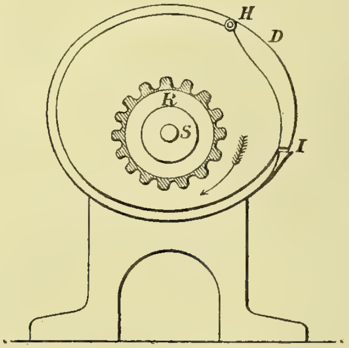
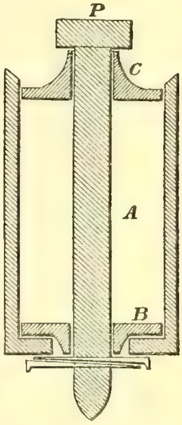


Fig. 844 shows a front view of the masticator, the case being removed; and Fig. 845, an end view, representing the excentric position of the fluted roller. The speed at which this roller revolves should not exceed 30–40 rev. a minute for strong masticated sheet rubber; a greater speed may be used where the object is simply to partially work for grinding purposes. The roller R is cast with a shoulder projecting about ½ in. above the plates at each end, inside the frame, to prevent the lubricant reaching the rubber. The door O, which is similar to a strong grating, is hinged to the upper part H of the frame, and is secured, when working, by a wedge fitting between the door and a recess formed by it in the lower part I of the frame. The strong toothed-wheel G is keyed to the fluted roller R, and worked off a pinion on the main shaft. The steam inlet is at S. The roller, by its excentric working, kneads the rubber, and by the alternate expansion and contraction in the upper and lower parts of the machine, a new surface is being continually presented to the roller. A 12-in. block will require 3–6 hours' working, to yield a good uniform sheet when cut up. The length of the machine is an important matter: the longer the block, the less is the waste in cutting the ends true, and generally the same is required whether the masticator will work up 40 or 240 lb. of rubber. These machines are made of a size to take much larger quantities of rubber; but there is a limit to the size when required for fine cut sheet: a block of 240–260 lb. cannot well be exceeded for this purpose. The diameter is generally uniform; the length only is increased when extra quantities are to be worked up. A masticator which will give a block 12–13 in. in diameter, with a 3-in. hole in the centre, is the most practicable; if this diameter be exceeded, the heat from friction will be extreme, unless the speed is very low. Should the charge be stopped by the block not going round with the axis, it may be forced down with a crowbar, so as to grip the axis, when it will be instantly carried round. When indiarubber is being over-masticated, it emits a peculiar odour, as if being roasted, and the block will be full of holes or cavities, and will have a darker colour.

Block Rubber.—After the block is taken from the masticator, it is forced into strong cast-iron moulds, which are first moistened inside with a little soap and water, to act as a lubricant. The blocks are produced in two forms, depending upon the means at hand for cutting them up:—(1) They are forced into long iron boxes, fitted with covers, which are forced down by a screw-press; as the mass yields, an extra turn is given to the screw. The block remains in the press for a few days or a week, when it is taken out, and placed in an ice-house or cool cellar. (2) Cylindrical moulds are now most generally employed, since from them are obtained blocks which can be cut up into continuous lengths, whereas the other method will only yield sheets about 6 ft. long. These moulds, Fig. 846, consist of a cast-iron cylinder A, carefully turned inside, and sometimes enamelled, with a recess or projection at the bottom, upon which rests a strong circular plate or disc B, with a 4-in. hole in its centre. This is first fitted into the mould, then the rubber is forced in by sledge-hammers, and removed to a powerful screw or hydraulic press, where it is forced fairly down into the mould. On the top of the block, fitting evenly into the mould, is placed an iron plate C, similar to the one at the bottom; and through the central hole, is forced a strong bolt or pin P, which passes through the rubber and the hole in the bottom plate of the mould. After the whole is well pressed, the pressure on the blocks is secured by keys or wedges, which pass through a slot cut in the lower part of the bolt, and can then be removed from the press to make room for other blocks. During the day, these blocks and moulds are again passed into the press, and forced with the screw, until they yield no more when other wedges are driven in as before. They are then transferred, without removal from the moulds, into a cool cellar or ice-house, until perfectly set and hard, when the moulds are emptied. The blocks remain in ice until required. They are sometimes hardened by being placed in a strong current of cold air, such as a chamber opening into the main shaft of the factory.

846.



Other methods are in use for obtaining blocks of rubber from the raw and washed articles, which consist in forcing it into moulds without masticating, and consolidating it by placing the moulds, keyed or wedged together with their charge, into a heater at about 116° (240° F.) for a few hours. Washed Pará yields good sound blocks in this way, but the rubber is deprived of more of its strength than if masticated, and is darker in colour.

Sheet Rubber.—The blocks are next cut up into sheets of different thicknesses. The square blocks are clamped to a plate, which can be raised to any height, according to the thickness of sheet required; this passes forward to an oscillating knife, which slices-up the rubber. The knife can be set in the opposite direction, so as to make another cut as it passes back again, and so on. The cylindrical blocks are forced upon a stout spindle, of the size of the bolts passing through them; this spindle rotates in front of a similar, though much longer, knife; the thickness of sheet is regulated by the feed-wheels, which are changed as required; and when the machine is once started, a block can be cut without any further attention, unless demanded by a defect in the machine itself, which occurs generally in the friction arrangement which works the feed-gearing.

These machines are worked at very high speeds, and a good supply of water is kept continually flowing over the knives. The sheets are generally hung up to dry and season, and are soaped, and laid carefully one on the other, or rolled up for stowage. This cutting-up must be done in a cool place, for if the rubber gets soft, it must be again placed in the ice-house to harden; soft spots or patches in the blocks will lead to inequalities in the thickness. These sheets are manufactured for tobacco-pouches, tubes, and other articles which are required from masticated rubber; such have a series of very fine lines or marks, which correspond with the strokes of the knife in cutting. Raw Pará, or just crushed between rollers first, gives a curiously mottled sheet, very strong, and not so easily acted upon by grease or exposure; it is consequently much used for the backing of wire "cards," and is even said to be as durable as leather for this purpose. The production of this sheet is a specialty with a few manufacturers, who cut up the raw article, and wash it at the same time in a kind of mincing-machine, in which a series of knives work backward and forward, or transversely, as required.

Tape Rubber.—Indiarubber fillets or tapes are cut from sheets, by winding the quantity required upon a wooden mandril, and securing the last lap, so as to keep the whole firmly together, either by means of a little naphtha or solution of rubber in naphtha. Knives are forced against the rubber as it revolves in an ordinary lathe, whilst a jet of water flows over them. A series of fine cutters, worked by a self-acting slide-rest, may be used in the same way to produce thread.

The rubber, when cut, is very weak, in fact it cannot bear stretching at all. It is run off the rollers or mandrils into a wooden zinc-lined tank, containing water heated to 60° (140° F.); this process seems to anneal or seal the edges, for, on hanging up for a few days after this operation, it is found to have acquired extraordinary strength. By carefully stretching it, and keeping it distended for some time, it remains elongated; when thrown into warm water, it instantly regains its original dimensions, but is much strengthened; by repeating this, its tensile strength may be increased 5-6 fold.

In passing tapes and threads into hot water, some care is required, as if they are allowed to stick too closely together, they are spoiled. After standing in the warm water for a little time, they are passed through the hands into cold water, to remove the stickiness, and are hung up to dry. Soap lye, alkalies, methylated spirit, and white finish, are sometimes used to prevent this stickiness. In telegraph work, water alone is used, as foreign matters prevent consolidation when heating. Rubber which has been passed only through methylated spirit, much better resists decay; this may be due to the wood-naphtha present.

Stretched rubber keeps longer than unstretched; this is not easily explained, although it seems that decay is a matter of simple oxidation. It must be preserved from direct sunlight and heat; if heated, it rapidly changes into a viscid substance, unless vulcanized. If, at this stage, it be kept in a cool dark place, it undergoes no change; but if it be heated, and then set by under the same conditions, it will gradually soften, and become rotten, after a time apparently drying up into a brittle resinous-looking substance. These changes are, according to the late Dr. W. A. Miller, due to the direct combination of oxygen with caoutchouc. The liquid condition which precedes this drying-up is not satisfactorily accounted for.

Dunlop's tape-cutting machine, Fig. 847 is very convenient for producing fillets for insulating telegraph-wire. Discs of rubber, cut from a cylindrical block, are secured on the vertical shaft N, by screwing down the nut O; by turning the handles T, the rubber is moved up to the fluted brass roller M; the shaft C, worked by a band, gives a uniform motion to M, through the worms F G, and the spur-wheels H I K L. As the discs are cut away, N revolves at a higher speed, and with it the whole of the feed-gearing, so that the tapes are cut of a uniform thickness.

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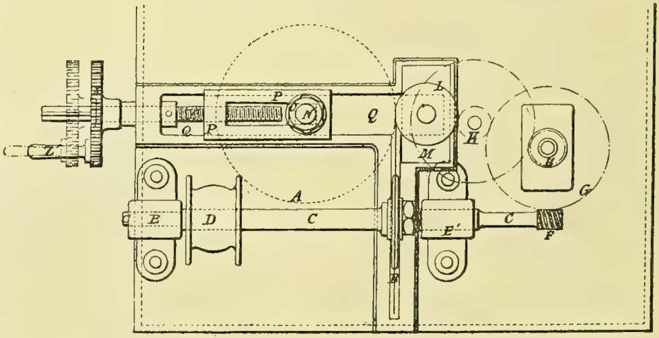


Thread Rubber.—Thread is frequently obtained from spread vulcanized rubber; the red which is made with antimony, and the black with sulphide of lead, are the most durable; vulcanized pure rubber more quickly gets rotten. The spread sheet is first desulphurized, and is then wound very evenly and tightly on a wooden mandril, and is uniformly stretched; the whole is well bound up with canvas, or, preferably, a sheet is cemented over it; it is then cut up in an ordinary lathe, or the sheet is laid on a table, and cut up by a series of traversing circular knives.

The sheets, either spread or masticated, are lapped around a mandril, and mounted in a lathe with a self-acting slide-rest. A cutter moving from the circumference to the centre cuts off threads from its ends. After each cut, the tool is moved. Dunlop's improved machine provides for the rapidly simultaneous motion of the cutter in its outward and onward direction, by a rocking-shaft attached to a sliding-arm, on which the tool-holder is linked. This shaft receives its motion by means of two curved tails attached to it, and which are acted on by studs on the faces of two wheels, one on each side of the curved tails. The studs, acting on the two tails, alternately produce the rocking movement; the wheel which produces the inward motion, or cut, carries usually six studs, and moves slowly, so as to work the cutter gently into the rubber. The feed motion is given by means of a cam on the axis of the last-mentioned wheel, which acts on the lever of a clutch, and clutches for a time a spur-wheel, which drives the feed-screw. The length of time during which the clutch is held in, so as to drive the feed-motion, is regulated by a disc in connection with the feed-screw; this disc has notches in it at regular intervals, into which drops a projection on the clutch-lever; and when this lever is raised by the cam, it cannot return until the feed-screw has travelled so far as to enable it to fall into the next notch on the divided plate or disc.

A series of very fine cutters carried on a slide-rest worked by hand is a convenient way for cutting up thread on a small scale. The sheet should be very evenly and tightly wound up, so as to avoid inequalities of thickness; and the last lap should be cemented down, or a sheet of compound, which can be recallendered, should be tightly bound over it and secured. This same method is applicable for cutting small rings, washers, &c. Round thread is obtained by forcing plastic rubber or its compounds through dies, whence it is received into water, to prevent sticking. It is dried and cured by the cold process.

Thread is tested by attaching a given weight to a certain length: it should not break, and little or no permanent elongation should be perceptible. Thread rubber is used for elastic webbing, braids, &c. In braiding, the threads of rubber are kept stretched to about double their natural lengths, so that on releasing, the braids have a full and even appearance. Elastic webbing is produced by cementing thin vulcanized sheet between two elastic woven fabrics, or by heating the vulcanized sheet between grooved surfaces, under pressure, so as to give it a corrugated surface. The oily matter given off in bodily perspiration is very detrimental to these webs, causing them to become quite sticky and soft, when their elasticity is completely destroyed. Webs may be tested by suspending them in a chamber heated to 38°–49° (100°–120° F.) for several days; in some cases, with slight distension. If moistened with a little coal-tar naphtha, they should show no disposition to soften.

848.

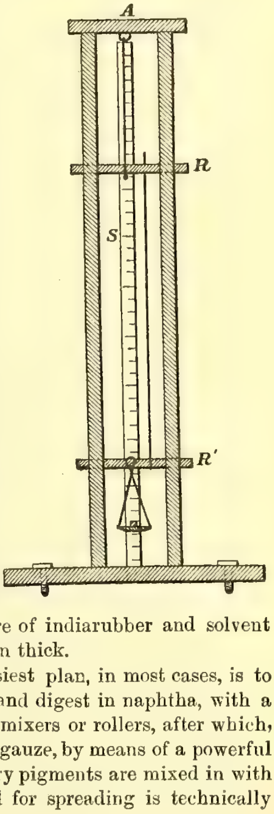


Fig. 848 shows a contrivance for testing rubber thread and tape. It consists of a light wooden frame A, 6 ft. high, bolted to the floor; the sides are slotted, so that the rollers R R′ can move freely through the greater part of the length of A; a paper scale S is attached to the back of the frame; R is rigidly attached at A to a movable support; the lower roller R′ carries a light scale-pan or hooks for supporting weights; between R and R′ is the material to be examined. Instead of weights, a delicate spring-balance may be conveniently employed.

Dissolving Rubber.—The solvents of indiarubber have already been alluded to. Those chiefly used are "solvent" naphtha (sp. gr. 0·850 at 60° F., boiling at 240°–250° F., and leaving no more than 10 per cent. residue at 320° F.), shale spirit, and benzol. Mixed with purified solid paraffin, by grinding together, rubber will acquire the property of melting by heat, and setting solid again when cooled. Solubility is promoted by grinding or working. Raw or washed rubber is less soluble than that masticated or ground, and well ground rubber is more easily taken up than that which has been less worked. All descriptions of raw rubber, in the same stages of manufacture, do not exhibit the same degree of solubility; the better qualities are less soluble than the inferior. Generally, washed rubber is used for dissolving for waterproofing. There is no doubt that in the case of Pará rubber, and some of the other cleaner kinds, the process of washing could be dispensed with, provided the raw article could be freed from adhering dirt, crushed between grinders, and afterwards hung up in a dry and warm room to season. The mixture of indiarubber and solvent is technically known as "solution" when thin, and as "cement" when thick.

When pigments are to be incorporated with the solution, the easiest plan, in most cases, is to grind the rubber and pigments together, run out into a thin sheet, and digest in naphtha, with a slight stirring as it is added. The finishing is performed by dough-mixers or rollers, after which, for the better class of goods, the softened mass is forced through wire gauze, by means of a powerful screw-press. Coloured solutions are sometimes used as paints: the dry pigments are mixed in with the rubber in a volatile solvent. The stiff solution of rubber used for spreading is technically called "dough." In handling this, the workman uses a little soap, so as to prevent it sticking to his fingers.

Spreading and Waterproofing Fabrics.—The treatment of fabrics which are to be "proofed" by spreading, consists in passing them through a pair of calenders, with the object of pressing down knots, and giving a smooth and even surface; after this, they are passed over a steam-chest, to expel moisture, when they are ready to receive the first coat. This is usually a different mixture from the bulk of the proofing, and is called a "sticking-coat," its object being to secure adhesion between the fabric and rubber; it is generally incorporated with colouring pigments, white or black, so as not to allow the general mixture to show through the cloth, or alter its appearance. A little oxide of zinc, or whiting, is used for white or light-coloured goods; Frankfort and other blacks are used for dark goods. The coats, as applied, are dried by passing over a steam-chest, when the fabric is again brought to the front of the machine for another coat, and so on. Some descriptions of goods have a finishing coat of better quality or mixture, in some cases containing no sulphur, nor any pigment whatever. The number of coats varies from three to seven, according to the class of goods, and the weight of material which is to be put on.

Machines are now employed which work on the continuous principle; but as they require more space, so as to allow each coat to dry in time to receive another, it is not certain that there is much gain in using them.

Methods have been devised for collecting the naphtha vapour and condensing it; the principal objections to these arrangements are that they interfere with the workman's being able to see his work as it passes over the steam-chest, and do not allow the naphtha itself to pass off so completely, owing to the partial obstruction. The enormous quantities of naphtha which are dissipated in the spreading-rooms of some of the largest establishments, afford sufficient evidence of the want of some suitable means for this object. One plan which has been used, and which certainly does collect some of the naphtha, consists of a rectangular iron hood, of such dimensions as to cover the steam-chest, or the greater part of it, and raised towards the middle, where it opens into a zinc chimney or flue, and passes down, outside the building, into a receiver, kept cool by running water. The vapour is mixed with so much air, which passes away charged with the naphtha vapour, that it is only possible to collect a very small proportion of the latter. Bruce Warren's method has been used with greater success. Its peculiarity is in collecting the naphtha vapour by indiarubber, which is capable of abstracting solvent vapours from air charged with them. The air, loaded with the vapour, is made to traverse a series of trays containing laminated rubber, which is required either for solution or for dough; or the naphtha may be recovered by distillation, and the rubber be used over again.

849.

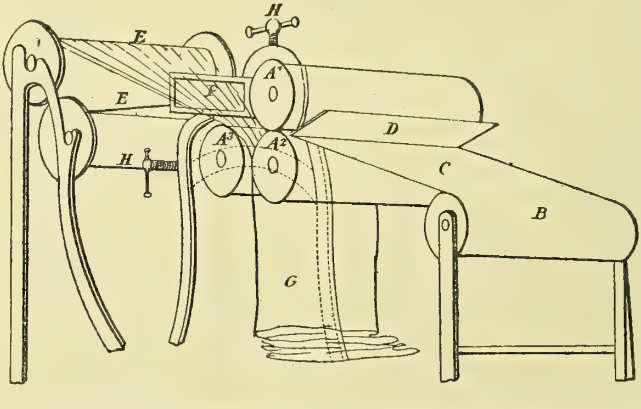


Fig. 849 shows an arrangement for spreading and doubling at one operation. B is a roll of fabric, passing under a knife D, in the front of which is placed, along the whole width of C, a roll of dough or cement. E E' are two beams of yarn, warped in the usual manner, passing through the reed F, and on to the adhesive surface of C. The pressure regulated by H on the rollers A^1 A^2 A^3 firmly unites the whole into one fabric G. Instead of the yarns, a woven fabric or fleece may be employed, as on B. The rollers are hollow, so as to admit steam for spreading guttapercha, pitch, resins, &c.

Drying Spread Fabrics.—After the goods leave the spreading-machines, they are hung up for a few days in a warm room, so as to expel the little naphtha which is retained by the rubber, and which it gives up very slowly. This drying helps to remove the smell of the naphtha, and prevents blistering in curing. The quality of the solvent used, and the temperature of the drying-room, determine how long this "hanging up" must last before curing. As indiarubber licks up, as it were, the vapours and odours which float about in the drying-room, it would be infinitely better to have a series of drying-rooms, so as not to hang up the more recently spread goods with those which have more or less completely lost their smell of naphtha. Goods which are cured by the cold process are hung up in the same way; but as they have always a more disagreeable smell, they should have a separate hanging-room to dry in.

Preparing Fabrics for Curing.—When spread cotton goods have become tolerably firm, or quite dry, they are wound upon hollow sheet-iron cylinders, for curing in open steam, or in a steam-jacketed heater. As the condensed steam spoils these goods, they are carefully wrapped up as air- and water-tight as possible. Since wool and silk are destroyed by the heat necessary to cure indiarubber in this way, the cold process is the only eligible method of vulcanizing. Very frequently, however, cotton goods are treated in the same manner.

In packing the goods for the steam-heater, care must be taken that the fabrics are wound without creases, and are not stretched, as the fibres of the cloth, after curing, will retain their distorted appearance Double textures are simply wound up; but "surface" goods are first carefully brushed over with very fine French chalk, no excess or loose chalk being allowed to remain. They are then wound up; but, as this necessitates the rubber surface coming into contact with the cotton surface, whereby it is liable to be marked, it is more usual to run two pieces together, with the rubber surfaces against each other. This not only prevents marking, but secures an even surface; blisters, from dampness in the cotton, are also prevented.

Double textures are obtained by passing the proofed fabrics through a pair of rollers (the doubling-machine), whilst the surfaces are still sticky or adhesive; these are vulcanized, if required, by means of sulphur incorporated with the compounds, and steam-heat. The doubling-rollers are of solid cast-iron, with turned surfaces, 6 ft. long. One is fixed, while the other can be moved by a lever, so as to admit the fabrics to be doubled. As they revolve in opposite directions, they draw the fabric through, and, when tightened up, press the two coated surfaces together.

Indiarubber Felt.—Indiarubber-felt, felt-paper, or Clark's patent felt, is used for a variety of purposes, such as covering damp walls, protecting silk and other wares from dampness during water-transit, covering telegraph-wire, roofing, &c. Although indiarubber is now entirely used, guttaperchâ, alone, or mixed with resins and other matters, has been employed. A pair of ordinary mixing-rolls, running at equal speeds, receive over each a cotton fleece, which is delivered from the carding-machines stationed on opposite sides, so that the two fleeces enter together between the rolls, and passing down through an opening in the floor, are led away, or rolled up. A soft dough is carefully laid between the rolls, and as the fleeces pass through, the rubber is squeezed into them. The fabric is vulcanized by incorporating sulphur with the rubber mixtures, and curing in the same way as ordinary spread fabrics. If made with good rubber and naphtha, it should not feel clammy nor soft, but should be dry and tough. Paper can be similarly treated; and, for damp walls, &c., would in many cases be as useful as cotton, while much cheaper. A few years ago, coppered cloth made from this felt was recommended for roofing purposes; it was abandoned principally because the rubber decayed, thus leaving nothing to support the metal. By vulcanizing, the rubber could be preserved, but it is not certain that the sulphur, by acting on the copper, might not be a source of fresh trouble. Iodine or bromine incorporated with the rubber would not be liable to this action on the copper. It should form a very useful protection for iron plates on ships, and might be used for a variety of purposes, as it could be cemented on, and, if the cement contained sulphur, or other curative agent, it could be vulcanized by holding a heated body against it.

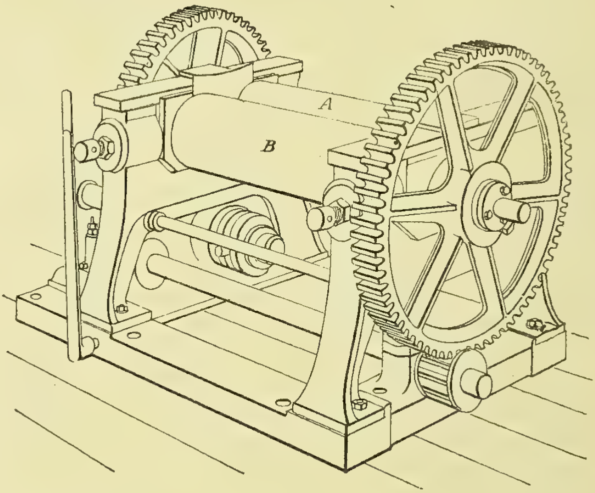
Grinding and Mixing.—The incorporation of pigments is effected between a pair of smooth rollers, running at unequal speeds (as 3 or 5 : 2). The rubber is first run through several times by itself, so as to soften it, and draw it out into sheet form; the pigments are dusted on as the rubber passes through, the process being continued until the whole is roughly blended. The rollers are then forced nearer together, by which the mixture is finely and more evenly ground, when it is ready for the calenders.

The grinders or mixers, consist of two very strong rollers A B (Fig. 850), 14–18 in. diameter, and 40 in. long, revolving inwards, so as to drag the rubber between them, and the rollers are hollow, so that steam or cold water can pass through them. They work in movable journals, as they require to be opened and closed. Equal-speed mixers are used for working the compounds into a more plastic and softer condition. They do not grind so well, and are consequently only used for special purposes. Grinders with shorter and stouter rollers are necessary for working up waste, and operating on more heavily-pigmented compounds. The less the compounds are worked or ground, the stronger will be the rubber when vulcanized or cured; on the other hand, if too hard, it cannot be so well calendered. Articles cured in moulds, as springs, washers, and valves, cannot easily get out of shape, or contract; but packing, and articles not cured in moulds, are shrunk well in boiling water before curing. As a rule the stronger the natural rubber is before mixing, the better and more elastic will be the manufactured article, if properly handled in grinding and mixing. An experienced calender-man can run out compounds into sheets with as little grinding as possible, whilst others require the rubber quite "killed."

Calendering.—Calenders are made with 2 or more rolls, according to requirement. Their object is to draw the compounds into sheets. Except in being more massive, and with the rollers arranged one above the other, and running at equal speeds, they are constructed in all respects the same as grinders. By bringing the rollers closer together, the sheets are made finer. A cloth is generally passed through the roll with the compound, and receives a coating on the side next the compound; it is passed through several times, until the desired thickness is obtained. All that is necessary is to raise the upper roll each time, and to bring the sheet from the front to the back of the calenders. For packing, the cloth is afterwards stripped off, therefore the first coating must not be run on too tightly; for sheeting, hose-cloths, &c., the reverse is aimed at.

Compounds for telegraph-wire are run out without cloth, and, on leaving the rolls, are received on a band or coated fabric, and wound up together. In some cases, the under side of the calendered compound is run over a roller, revolving in a trough of varnish made of shellac and methylated spirit, the object being to prevent sticking when wound on bobbins. Calendered strips or tapes are obtained by pressing down upon the roller, which carries the rubber round a series of cutters or dividers, the width of which can be varied. These strips are received in the same way, varnished, or otherwise. Care must be taken in these cases to keep the roller free from any soiling by the fingers, otherwise the compounds cannot be easily drawn off, but will be continually carried round. Highly worked mixtures cannot be so well managed as those worked for a shorter time, and moderately pigmented. As adhesion is essential between all the parts of a telegraph-wire, the compounds must not be calendered so hard as to prevent this.

850.



Calenders running at a slightly unequal speed are used for driving compounds into the meshes of fabrics; the grinding action opens the cloth by stretching, and forces the rubber completely through the fabric. Belting, hose, and packing-cloths, are thus treated. Sometimes a little naphtha or solvent is incorporated with the compounds, so as to make them more soft and sticky. Not unfrequently hose-linings, &c., are spread, instead of being calendered.

To avoid soiling the surfaces of a calendered sheet, it is usual to run a loose cloth, or, if both surfaces are calendered with rubber, two cloths with it, which also prevents sticking together. Finished sheets are brushed over with flour or French chalk: when the latter is used, the surfaces are permanently soiled; but when it is necessary to prepare these surfaces for cementing or joining, they are brushed over with flour, which can be removed when required by washing with water, taking care to allow all the moisture to dry off afterwards. Fig. 851 represents a set of 4-roll calenders, by Crossleys, Manchester: A B C D are 4 chilled-iron rollers, cast hollow, so as to admit steam or water. A D can be moved nearer to or further from B C, by screw-gearing, worked by a capstan or wheel W. It is general to drive the calenders by a special engine, so as to ensure a well regulated speed, which is not so easily attained from a main-shaft. S are spindles, for carrying drums, cutters, &c., necessary for the different calendering operations.

Valve-cutting.—Fig. 852 represents the most improved form of circular cutting-machine, manufactured by Crossley Bros., Manchester. It can be driven by hand, or by a belt from an overhead shaft. By means of the lever L, the cutting arrangement can be raised or lowered on the axis A; it is lowered gently by hand, while in operation. As it fits loosely on the axis, it is not carried around with it. Attached rigidly to the axis, are two square bars, each carrying a knife K, and a small can W for holding water; from these, pipes P deliver a stream of water in front of the knives, to keep them cool. When the knives, &c., are in position, they are prevented from shifting, by clamping to the bar. A screw enables them to be moved with accuracy. The sheet to be cut is placed quite flat under the machine; one screw is worked until the knife is in position for cutting out the central hole; the other knife is moved out for the required diameter; a belt working on the fast-pulley F sets the whole in motion, when the lever L being pressed down, the valve is gradually cut out. If no hole be wanted in the centre, one of the knives is removed, or drawn out so as to clear the sheet. A stop-cock, not shown, regulates the flow of liquid from W. The machine is bolted to a bench, so that a long sheet can be operated on. The knives should first be pressed down slightly, and the machine be driven slowly, preferably by hand, so as to just mark the dimensions before completing the cut. A circular knife is most expeditious for cutting up small articles, such as stationers' rubber. The article is first obtained in long strips, a gauge is fixed for the length on the table in front of the knife, and the rubber, moistened with water, is simply pushed up to it.

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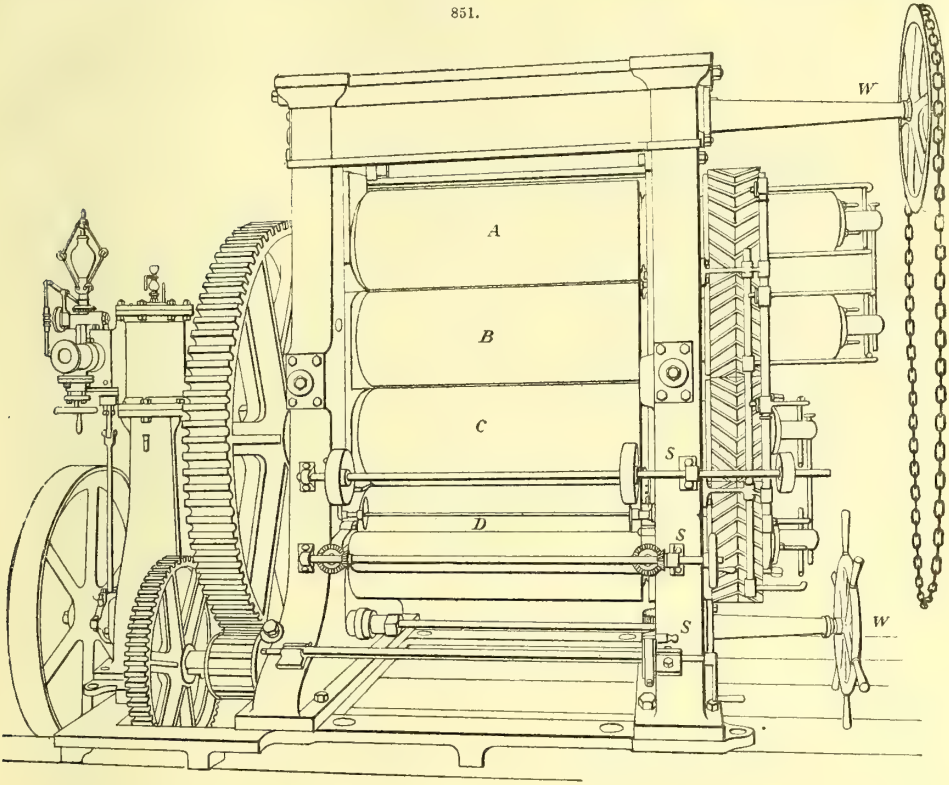
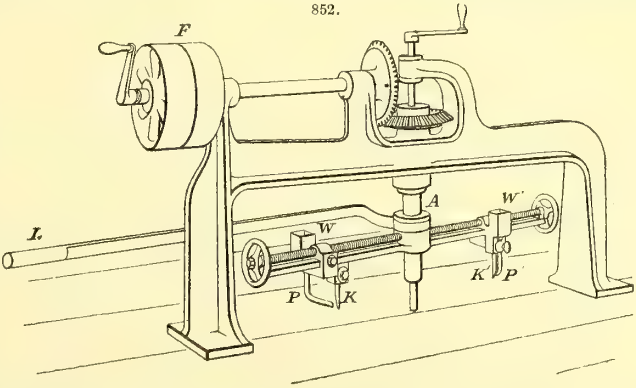


Insulating Telegraph-Wires.—The methods of applying indiarubber to this purpose are:—(1) by lapping fillets on the conducting-wires, as they are led away; (2) by passing the wire and fillets between a pair of circular cutting-discs. More frequently, the two methods are used conjointly. When the core is to be vulcanized, especially if the coatings are applied longitudinally, it should be evenly, but not too tightly, bound round with a cotton or felt tape. Special care is required in preparing all the materials: imperfectly masticated rubber, or compounds not sufficiently worked in the mixing-machines, will invariably lead to failure. The selection and preparation of the pigments cannot be too carefully studied. The conducting-wire will not remain central, if the rubber is soft or overworked, nor if the pressure between the discs on the upper and lower fillets is unequal. A hard rubber will not easily unite at the edges when cut, nor will the adhesion with the previous or subsequent layers be reliable. This is the most important object to be attained. The pigments

852.



must be well sifted and dried, the grinding and mixing should be of uniform duration, and the temperature be kept as regular as possible.

Telegraph-core is cured, either on drums, when it should not be too tightly coiled on, or by being laid down loosely on long oval trays; in the latter case, several trays are superposed. Small wires may be laid in a mixture of French chalk and sulphur, or may be drawn through a tar and sulphur bath. Joints are cured generally in a mixture of beeswax and sulphur, at a high temperature; they should be tightly lapped in two or more coverings of tape. The great point being to ensure consolidation of the rubber coating, cleanliness, freedom from damp, and careful binding, must be attended to.

Indiarubber cores are largely used for torpedo and military telegraphs, from the fact that they are less easily injured than guttapercha by rough handling or heat. As an insulator, indiarubber possesses a superiority over guttapercha, in having a much higher resistance, with considerably lower capacity; in practice, however, whilst these superior merits are retained, its manufacture is not attended with that certainty of success met with in guttapercha. In the earlier days of insulating with the former, the masticated form in tape was used, the lappings were consolidated by heating, and were not vulcanized. The coating rapidly decayed on exposure to air and light. This led to the introduction of several methods of applying vulcanization to the rubber, either by mixing sulphur directly with it, or by allowing an inner coating of rubber to take up, under the action of heat, a certain proportion of sulphur from a superposed coating, so as to produce perfect vulcanization with a very small quantity of sulphur. Crystallization of sulphur takes place, when it is used in excess, and an efflorescence follows, which renders the coating porous and electrically defective. Only a few pigments are admissible in this manufacture; most metallic oxides, except the black oxide of manganese (manganic dioxide), and the puce oxide of lead, can be used, as well as their carbonates and sulphides. Soluble salts are inappropriate; earthy minerals, as French chalk, silica, &c., which are not hygroscopic, are not objectionable; asphalt, pitch, and a few resinous substances in small quantities do no harm.

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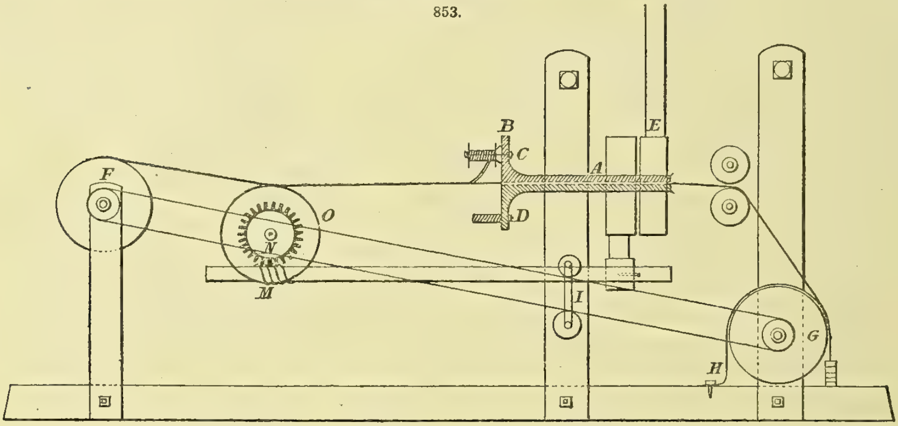

Indiarubber fillets are lapped around telegraph-wires by the "lapping-machine," Fig. 853. The frames are best made of wood, so as to avoid chilling the rubber in cold weather by contact with metal. In the construction, every precaution must be taken that no oil, dust, or grease can come into contact with the rubber or wire; consequently the driving-gear should all be placed under or below the machine. A hollow mandril A, carries a head-stock B, to the face of which are attached the spindle C, for carrying the bobbin of tape, and a balance-spindle D, as this machine is driven at very high speeds. To the mandril is fixed a pulley E, for driving the machine by a belt. The draw-off arrangement is worked off the same mandril by a worm-wheel M, working into a bevelled tooth-wheel N; to the axis of the same, is attached a small iron drum O, around which two or three turns of the wire are taken, and thence to the wooden drum F, where it is wound up. The wire is wound upon the drum G, which is worked by the draw-off gearing, a friction-plate or strap H preventing its going round too fast, so as to keep the wire rather tight. The drum F is turned round by a belt driven off G; this belt can be tightened or made slack by friction-wheels I, as its speed must be regulated, according to the diminishing diameter of the contents of G. The draw-off arrangement determines the length of lay; the friction on the bobbin regulates the tension on the tape, and consequently its thickness; a spring attached to the spindle can, by means of a small screw, give the necessary friction to the bobbin.

Indiarubber is applied longitudinally to telegraph-wires by means of circular cutting-discs, Fig. 854, grooved to the required size of the core. These cutters are movable, so as to admit of covering different sizes of wire. A stout iron frame A is firmly bolted to a wooden table. By means of the handle H, the upper disc can be lowered or raised for any final adjustment; it is essential that these discs be of exactly the same diameter, and driven at precisely the same speed. The discs D are made of Bessemer steel, about ½ in. thick and 8 in. in diameter, and are carefully turned, so that their cutting edges are just prevented from working on each other; a hole through their centres admits the spindles, which are supplied with nuts for screwing the plates P and discs D together. When more than one pair of these cutters is used, they are arranged so that the seams in the rubber coatings do not coincide; they are best at right angles to each other. Guides are placed in front of the cutters, so that the tapes entering with the wire are kept in their proper places; the portions sheared off are received in trays by the workmen. The tapes are wound up on flat circular plates, about 10 in. in diameter, which have fixed to them a circular piece of wood, corresponding in thickness to that of the tapes. The tapes must be carefully wound, so as to avoid sticking while being drawn off by the travelling of the wire, through the machine. To secure centrality, the pressure must be uniform, unequal tensions being avoided. The tapes must be of equal thickness, and, as near as possible, equally plastic; this is obtained by uniformity in grinding and calendering, and subsequent maintenance of equal temperatures. The condition of the compound must be such that a gentle pressure causes them permanently to unite at the recently cut edges. The surface of these tapes, forming the outside of the core, is varnished with shellac dissolved in methylated spirit, to prevent adhesion when wound on the bobbins.

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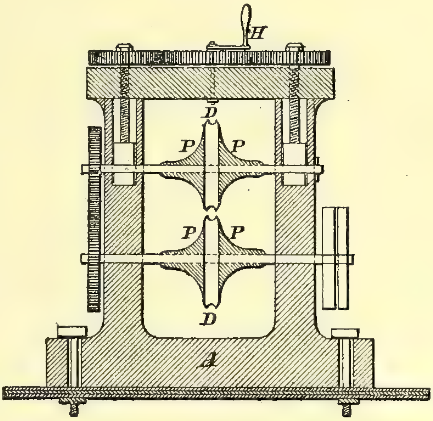

A form of cutting-disc used for making joints has the discs working outside the framework, and is moved by a handle. Similar appliances are convenient for making tubing, &c. The edges are well squeezed together, and the superfluous rubber is cut away by a rapidly revolving circular knife. Attempts have been made to use one tape only in covering wire; the air which is thus enclosed has been the barrier to its success, but it may be very conveniently adapted for making small tubing.

No material or compound is suited for an insulator unless it possesses a high resistance, and is impervious to moisture. A simple method of testing a sheet is shown in Fig. 855: E is an electrometer; W, a small weight of metal, resting on the sheet S, and occupying the central portion of its surface, so as to give a margin of 1 in. all round; the sheet is placed flat on a table or board. A dry glass rod, or ebonite tube, is rubbed with a silken cloth, and the knob of the electrometer is touched with it, when the instrument, if in good order, holds the charge thus communicated to it for several minutes, without an appreciable loss. It is now connected with the piece of metal resting on the sheet, and recharged. An idea of its insulating value is readily obtained by noting how long it takes for the pointer of the instrument to fall through any proportion of the arc to which it was originally deflected. Fig. 856 shows a simple method for testing the impermeability of a material to water. The material is made into a small bag B, which is filled with water, and closed with a metallic stopper, reaching down into the middle of the bag. It is placed in a tin box, filled with water. By pressing down the key A, the interior of the bag is charged by the battery, and on releasing A, and pressing down B, the charge thus communicated is sent through the galvanometer G. The deflection is noted. The bag is now recharged in the same way; on releasing A, the charge left in B is measured, after a few minutes, by pressing down D; the difference between these deflections will show what proportion of charge has leaked through. As sulphur rapidly destroys copper-wire, the latter should be well tinned, or coated with solder, when insulated with vulcanizable compounds.

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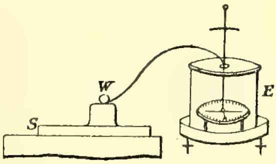

Ozokerit and paraffin-wax mixed with indiarubber have been recommended as insulating materials. Warren's "bromo-," "iodo-," and "chloro-" caoutchouc wires are made by imbedding rubber-covered wires in mixtures of French chalk and iodine, or bromine, or by immersion in solutions of these agents, or in an aqueous solution of chlorine. Rubber thus treated has all the properties of being vulcanized, and, according to the time of immersion, will be rendered soft and elastic, or hard and inelastic, like vulcanite.

Other Applications of Indiarubber.—In America, rubber incorporated with iodine or bromine, mixed with turpentine and a very small proportion of sulphur, has been used for dental purposes; it cures perfectly hard at 149° (300° F.), in short heats, and the incorporated pigments retain their bright or natural colours. Dental rubbers are supplied in the uncured state, and are vulcanized in a plaster mould. The pigments principally employed are the red sulphides of mercury and antimony, oxide and sulphide of zinc, with 40–50 per cent. of sulphur. It is important that no pigment used should be capable of being removed by weak organic acids; on this account, oxide of zinc is more often replaced by sulphide. Newborough employs a little iodine or bromine, mixed up with turpentine, which, in this form, does not act immediately on the rubber; this enables him to use a considerably smaller proportion of sulphur, to obtain a perfectly hard compound at 149° (300° F.) in a much shorter time, and in addition, the colours of the pigments are less damaged. It is very probable that the use of iodine and bromine, with or without sulphur, may lead to the introduction of less objectionable pigments than those now employed. Some of the earthy silicates are not seriously affected in colour by sulphur, when incorporated with rubber. Compounds containing red antimony are sometimes met with containing Spanish brown, rose-pink, &c. Indiarubber mixed with phosphorus was patented by Parkes for producing moulds for electrotyping. Rubber is extensively used for giving a body to petroleum oils, when used for lubricating.

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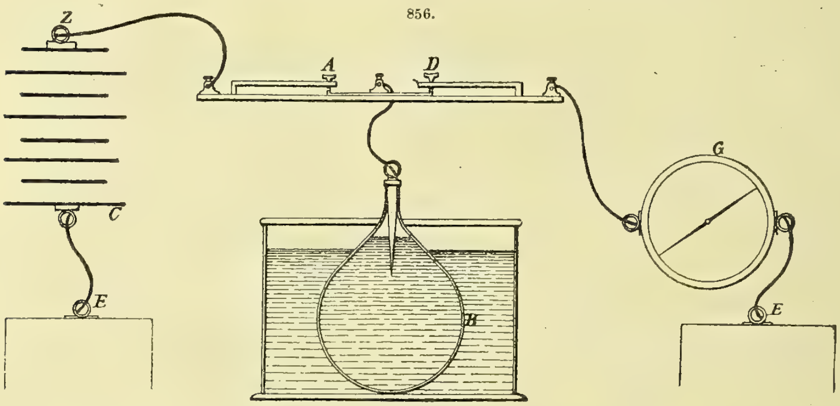


Curing or Vulcanizing.—When indiarubber is mixed with sulphur, and heated sufficiently, it acquires properties strikingly different from those of the original article. The tests which are now accepted as evidence of vulcanization may be contrasted with the behaviour of unvulcanized rubber under the same agents:—

UNVULCANIZED OR RAW RUBBER.	VULCANIZED OR CURED RUBBER.
Heat.—Cannot be heated above 115° (240° F.) without decomposition setting in; if not at once visible, becomes very perceptible in a few days at most, especially on exposure to air or light. Heated to 118°–121° (245°–250° F.) for a little time, becomes soft and sticky, and finally is converted into a viscid liquid. Becomes quite hard at 4° (40° F.), and is readily softened by being held before a fire, or plunged into water heated to 21° (70° F.).	May be heated above 115° (240° F.) without any visible change, and does not become soft or sticky if heated for hours at 121° (250° F.). Higher temperatures, as 132° - 138° (270° - 280° F.), continued for a few hours, may render some goods soft and clammy, which is regarded as indicating imperfect manufacture. No change is perceptible when placed in a freezing-mixture, unless the rubber is imperfectly vulcanized. Water heated to 21° (70° F.) has no marked effect on its hardness. The effect of cold is more readily perceptible than that of heat on imperfectly cured rubber.
Stretching.—When stretched and kept drawn out for a little time, will retain more or less its elongated condition, and, if heated, will return almost to its original length.	Should be perfectly elastic or nearly so. Imperfect vulcanization is soon perceived by stretching, and measuring its increased elongation. Heat causes it to return slowly to its original length; if more thoroughly cured, it has scarcely any effect in this direction.

UNVULCANIZED OR RAW RUBBER—*continued.*	VULCANIZED OR CURED RUBBER—*continued.*
Solvents.—Coal-tar naphtha dissolves it slowly, but soon renders its surface slimy and sticky. Other forms are more readily acted on by solvents, and yield in a few hours a gelatinous-looking mass. On evaporation, the rubber is left more or less sticky; by completely driving off the naphtha, the rubber is recovered either with its original properties unaltered, or perhaps a little soft. Inferior rubbers will remain sticky.	Unless highly cured, swells a little, but does not become sticky; if highly pigmented, it is rendered short and inelastic. It is not made sticky, unless under a very prolonged immersion, and heating. On evaporating off the solvent, the properties of the rubber are found unaltered, if of good quality.
Roasting.—Quickly passes into a tarry condition, and emits a peculiar odour, not garlicky, nor sulphuretted. The uncharred portions quickly pass into an unctuous mass, after a short exposure to the air.	Chars on the parts exposed to the heat, but does not so easily melt, and emits an offensive smell of garlic, which is modified by the proportion of sulphur. The uncharred portions remain unaltered if exposed to the air.
Sulphur.—Immersed in molten sulphur, it is converted into vulcanized rubber.	Thoroughly vulcanized, is not affected, but more or less effect will be produced as the rubber is imperfectly saturated with sulphur.
Uniting.—The freshly cut edges are easily joined by pressure with a little heat.	The freshly cut edges may show a slight tendency to unite, but a joint cannot be made without proper appliances, especially if well cured.

Vulcanized rubber is obtained either by heating indiarubber mixtures containing sulphur, or by immersing indiarubber in sulphur or mixtures containing sulphur. Chloride of sulphur, iodine, bromine, chlorine, hypochlorous acid, sulphurous acid, chloride of arsenic, and a few other chemical agents, have an action on indiarubber approaching vulcanizing. This "changing" of indiarubber was discovered by Parkes; it is now known as "cold curing" or "semi-curing." Chloride of sulphur is the only agent employed on a large scale. Warren's method of treating telegraph-wire has been already mentioned.

The present methods of vulcanizing, which will be considered here, are:—(1) when sulphur and a high degree of heat are employed—(*a*) the "water cure," where water heated by steam is the medium for heating; (*b*) the steam heater, where direct steam or a steam jacket is used; (*c*) hot air, or dry heat; (*d*) sand-bath; (*e*) high-boiling liquids; (*f*) sulphur, alone or in compounds, used in a molten state; (*g*) metals, either molten or heated surfaces. (2) Injecting hot air or gases, steam, water or other fluids, or metal, into the article to be vulcanized. (3) When little or no heat is employed, and chloride of sulphur and similar changing agents are used.

Circumstances arise where each of these methods is specially applicable; there is, however, a difference of opinion on the merits of some as compared with others where the same objects are to be attained. The different methods of heating are worthy the attention of the general manufacturer, because although he may not often require to use them, conditions requiring special treatment in vulcanizing frequently crop up. Some of these methods are applicable for heating any particular part of an article, when over-curing would result from re-heating the whole. Jointing telegraph-wire long lengths of hose-pipes, &c., requires contrivances not found in every factory, and which are useful in other ways, and for other purposes.

(1—*a*) The water-heater is simply a short boiler set on end in the ground, and is usually employed for curing sheet packing. It is most important that the articles should be well bound up, and immersed completely in the water. The heat is run with a thermometer dipping into the water, and the steam is injected into the centre of the heater. The degree and duration of the heating are the same as in steam-curing. The principal advantage of these heaters is that longer lengths of packing can be cured at one time, than would be possible with the steam-heater, without giving extra length, which, in many cases, would scarcely be convenient. To this must be added the fact that blistering is not so frequent if the sheets are well rolled upon the drum, and probably this capability of binding and wrapping, which would not be possible if the sheets were laid out flat, unless at great trouble and expense, gives an extra safeguard against damage by blisters. The packing is run taut upon a drum, with canvas, to prevent sticking, and is well wetted at the same time. When cured, it is, whilst hot, laid out flat on a smooth table, to cool. The allowance for shrinking and thickening by contraction is more easily made, and can be more depended upon, than when running in steam. The fabric used for binding is strong canvas.

(1—*b*) The ordinary steam-heater is similar to a steam-boiler; its opening is fitted with a strong iron cover, secured by bolts and nuts. The goods are packed in French chalk, on an iron carriage, running on a set of small rails. The carriage is drawn out by a rope and windlass.

Steam-heaters for curing telegraph-wire have been made to open at each end, the object being to pack the carriage at one end, whilst the heat is being run with core packed on a similar carriage at the other end; when one is drawn out, the other is ready to go in. Steam-heaters should be well covered with felt, brickwork, &c., to avoid loss of heat, draughts from open doors, &c. In curing goods by steam, much care must be exercised, as fabrics cannot be heated without having their strength more or less impaired. The compounds used should readily vulcanize at the lowest temperature, and the thickness of the goods should not be such as to retard the heating, and lead to some parts being over-vulcanized, and others only slightly cured. The only way to avoid this is to heat very gently for some time, so as to make sure of an equal distribution of heat, and to use pigments which will assist the vulcanizing, either chemically or mechanically, e. g. the better conductors of heat. There are several special kinds of steam-heater in use for curing belting, valves, hose, tubing, joints in telegraph-wire, and coated fabrics. Double or jacketed heaters are used where condensed steam would spoil the goods; and the extra precaution may be taken of wrapping the latter in waterproof cloths.

(1—*c*) The hot-air heater is made so as to revolve, or, if stationary, the goods themselves are turned on a drum. A series of gas-jets, burning in a close cupboard or chamber, makes a convenient heater; the only precaution needed is to place over the jets a sheet of metal, to avoid the direct scorching heat of the burners. A spindle, passing through the ends, carries a drum, on which the articles are packed; by means of a handle, continuous or intermittent motion is given.

A special form of heater is made for dentists who cure their own forms for gums, &c.; the heat is obtained either directly from a gas-burner, as in a stove, or through the medium of steam, generated from a small boiler attached to the stove.

(1—*d*) The goods are imbedded in sand, French chalk, &c., in a bath which is heated by gas.

(1—*e*) The goods are immersed in glycerine, covered up, and placed in a steam-heater, or direct heat may be applied by a sand-bath. Solutions of the alkaline and earthy polysulphides have recently been introduced for curing. Under heat, they yield part of their sulphur to the rubber.

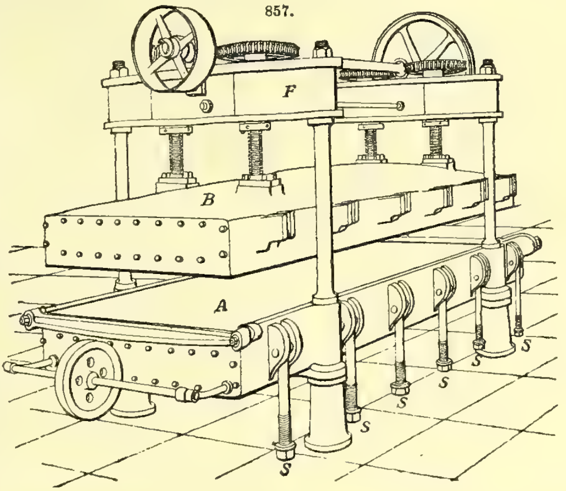
(1—*f*) In curing with the sulphur-bath, the article to be vulcanized abstracts the requisite amount of sulphur; the same takes place, though not so well, with heated tar and sulphur, or beeswax and sulphur. In these methods of curing, the heat is applied much higher at the start than with steam —generally 127°–149° (260°–300° F.), consequently much less time is required. If the articles are bound up, the material should be capable of allowing the sulphur to pass through; they should also be kept gently moved during the whole time. Immersion in water immediately after the sulphur-bath, renders the adhering sulphur less troublesome to remove. Articles made from masticated rubber are more generally cured in this way, and are more durable than if ground with sulphur in the mixing-machines. A mixture of beeswax, sulphur, and rosin, is largely used for curing joints in telegraph-wire. The mixture is heated to about 138° (280° F.), when the joint, well bound with tape, is immersed in it; the heat is raised to 149°–160° (300°–320° F.), in about 20 minutes, and the joint is kept at the same temperature for 1–2 hours. It is essential that sulphur be in excess in this mixture, otherwise it will be partially abstracted from the article to be vulcanized.

(1—*g*) The press shown in Fig. 857 is now extensively adopted for curing large valves, belting, &c. It consists of two parts: the bottom A is stationary, whilst the upper B is movable; the whole is connected with a strong framework F, which supports the gearing for raising or lowering B. In the belt-press, A B are quite flat; for valves, A is cast with a rim or edge, so that B fits closely into it. The surfaces of A B must be quite smooth. The article to be cured is laid perfectly flat on the bed-plate A, and B is carefully lowered down upon it; the two parts are firmly clamped together by the screws and nuts S; steam is admitted into A B, so that the article is in reality cured by means of the heated metallic surfaces of the two steam-chambers. Loss of heat is avoided by coating the chambers with felt. The lower plate of the belt-press may be grooved to the width and depth of the belt; but more conveniently, shifting-plates are used, grooved to fit the belt, and having a flat iron bar, of exactly the same width, placed on them. The upper plate is lowered, steam is admitted as before until the portion in the press is cured; this is then drawn through, so as to admit of another section being cured, and so on. Belts thus cured have good square edges, and the pressure used causes the layers or plies to adhere more firmly together. Blowing or blistering, from dampness in the cotton, &c., is avoided by puncturing the uncured belt at a little distance from the press; the punctures disappear in the press. About 20 minutes is required for curing each length of belting. Red-lead and similar pigments which assist the curing are used in the compounds. Besides curing rapidly, it is equally essential to cure with as low heats as possible, so as not to weaken the fabrics forming the plies of the belt.

A press or heater for curing joints in telegraph-wire consists of a small upright boiler for generating steam. A jacketed tube longitudinally divided A B (Fig. 858), is attached to the boiler, in such a way that the parts can be brought together, and enclose, in their annular space, the joint to be cured or vulcanized. After clamping the whole together, steam is admitted into the concentric spaces through I, the condensed steam being led away by attaching rubber tubes at O.

Many small articles are cured in metallic moulds, under pressure in the press, or in open steam. For many kinds of goods, it is important that the metals forming the moulds should not be readily acted on by sulphur during the heating, as a portion of the sulphur would be abstracted, and leave a stain of the metallic sulphide on the goods; consequently, sheets of packing, if cured in the press, are prevented from coming into contact with the metal, by sheets of cloth or paper. Tin is the most convenient metal for resisting the action of sulphur; zinc sulphide, being white, indicates the suitability of zinc for coating moulds, &c. All new zinc surfaces should be well cleaned before use; a good plan is to dust them over with sulphur and French chalk, and heat them in the steam cure several times, or they give rise to very troublesome blistering. Boiling with caustic soda helps to prevent this, but is not certain in its action. Brass moulds should be well tinned. Ebonite, or hard-cured rubber, forms very convenient moulds, well adapted where metallic surfaces would be objectionable, from staining, &c. Stains from tin moulds or tinned surfaces are removed by leaving the cured articles in hydrochloric acid for some hours.

857.



Fusible alloys, mixtures of tin, lead, antimony, and bismuth, melting at low temperatures, have been proposed as curing media.

(2) Canvas hose is sometimes cured by passing steam through it; the strength of the fibres is less affected, and the liability to loosen the coating by dampness through the fabric is entirely avoided, as the steam comes into contact with the rubber surfaces only.

In water and steam heating, the temperatures are now indicated by thermometers, pressure-gauges being found unreliable. It is usual to reach the maximum gradually, so as to allow the articles to get thoroughly warm and softened, without the vulcanizing action setting in. When the heater is closed up, $\frac{1}{4}$ hour, or even much longer for thick masses of rubber, is usually required for reaching the first 66°–93° (150°–200° F.), which should be kept up for 30 minutes or so; during the next 30 minutes, the temperature may be allowed to rise to 115°–121° (240°–250° F.), which is maintained for 1–2 hours; the temperature is again gradually raised to 138°–144° (280°-290° F.), and kept constant for 1–2 hours. Very thick masses of rubber may require several hours for curing. Heats too rapidly changed cause blisters or sponginess, followed with bursting of the mass, even if enclosed in strong iron moulds. Vulcanite or ebonite is finished off at 149° (300° F.).

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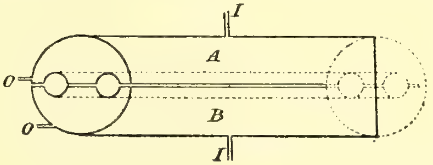


(3) Parkes' process of vulcanizing with chloride of sulphur is extensively used for surface curing, such as single textures for garments, and sundry small articles manufactured from masticated sheet rubber, as tobacco-pouches, tubing, rings, &c. The chloride is mixed with 30-40 times its bulk of carbon bisulphide for ordinary fabrics; but for solid rubber goods, much more dilute solutions must be used, and a longer immersion allowed, than with stronger solutions, since the surfaces would be overcured, and crack. Chloride of sulphur in vapour is preferable in many cases to the mixture in carbon bisulphide. The articles are then suspended in a lead-lined chamber, well varnished with shellac, and heated by steam-pipes; the chloride is gently evaporated, either by placing it in an open dish on the steam-pipes, or by using a small retort, the end of the tubulure of which passes into the chamber. The chloride is evaporated by a small gas-burner. Chlorine, bromine, hypochlorous acid, and several other vapours, can be used in the same way. Although Parkes uses these vapours with solvents of rubber, they act equally well, and in many cases more certainly, without them.

Several improvements for curing double textures have been recently introduced, the most important of which is the Silvertown process. This consists in passing the rubber surface of each piece to be united over a roller, revolving in a mixture of chloride of sulphur and bisulphide of carbon; the acid mixture does not come into contact with the fabrics, so that no injury can happen either to the colour or the fibres, and the most delicate tissues can be treated. Another process, patented by Anderson and Abbott, effects the curing by suspending the fabrics or completed garments in a chamber, which is afterwards charged with the vapours of chloride of sulphur; it is questionable how far this method can be depended upon, without injury to the fabrics. If the colours are discharged by the chloride of sulphur, they are brought back by placing a dish of liquid ammonia in the drying-room.

Single textures are cured by passing the coated surface over a roller, revolving in the curing-mixture, as above. The fabrics are run on to a large drum, and the cured surface, which is still sticky, is kept from coming into contact with the cloth surface, by making the drum pick up a roller whenever its arms pass the frame which supports them, so that between each two layers of material there is a space of about 2 in.; as soon as the bisulphide has nearly all evaporated, the fabrics are run on to a roller for hanging up.

Indiarubber Paints or Varnishes.—Indiarubber paints or varnishes can be made by mixing pigments with a little thin solution in some easily volatile solvent; after the solvent has evaporated, the film of rubber can be cured by the application of a little of the cold-curing liquid. The pigments easily retain their colours when applied in this way; but if mixed up with oil, they are not so elastic after a little exposure, and become harsh, and crack.

Varnishing Indiarubber Textures.—Single textures, when cured, are well wiped over, and varnished with shellac dissolved with liquid ammonia in water. Lamp-black is added for black goods; bleached shellac or seedlac is best suited for white or light-coloured goods. The varnishing is performed by passing the fabrics over a roller running in a trough of varnish, or better still, by letting the varnish fall on the rubber surface. It spreads of itself, the excess being removed by passing under a close-fitting scraper or pad. It is dried by running over a large drum or cylinder, heated by steam. Small articles are varnished by a soft sponge.

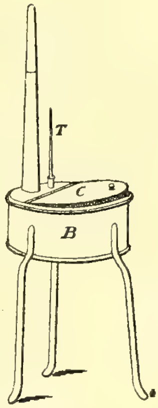
Joining Indiarubber Textures.—Cured or uncured fabrics are joined for garment-making and other articles by cementing together with thin solution. Camphene was largely used a few years ago for softening the edges of rubber for uniting. It leaves the rubber more sticky than any other solvent does. Its present price precludes its use on a large scale. Several coatings are applied, each being allowed to get nearly dry before the next is rubbed on; the two adhesive surfaces are then well rolled down by manual labour, and the excess of cement which oozes out is rubbed off, when nearly dry, by a piece of masticated block rubber. Double textures are stripped, so as to cement the rubber surfaces, by applying first a little solvent, which renders the stripping-off easier. In spreading, it is necessary to coat one of the fabrics with less pressure, so as not to drive the rubber into the meshes of the cloth. Such coatings are specially designated "stripping-coats." Without such arrangement, double textures could not be made with watertight seams.

Testing Cured Goods.—Well-cured rubber should swell but slightly in cold tar-naphtha, and leave no imprint of the finger-nail when pressed into it. On stretching, it should draw out evenly; sudden or gradual extension should produce but little, if any, permanent elongation. Defects in curing are air-cavities and blisters due to insufficient sulphur, heat, or moisture, when the articles may be spongy and soft, though tolerably well cured. Over-curing imparts a harshness to the surface. Under-cured rubber is clammy, more or less adhesive when the freshly cut edges are pressed together, swells readily in naphtha, and retains a considerable elongation on stretching. Buffers, springs, &c., are tried in a screw-press for two or three days. Diving-dresses, fishing-boots, powder-bags, &c., are filled with water, and allowed to stand for several hours. Steam is used for those articles made of solid rubber; any defect is rendered visible in a few minutes by damp spots appearing on the surface. Fire-hose and other strong tubes are tested by forcing water in until the required pressure is shown on a gauge. Defective proofing is shown by taking a piece of the fabric, with the rubber surface upwards if a single texture, and placing it over a sieve or deep hoop, so as to hold water; after some hours, water will have leaked through to the under side, if the proofing is imperfect. A test used by the Admiralty for vulcanized rubber and sheeting is as follows. The sample is placed in a hot-air oven B (Fig. 859); through the cover C passes a thermometer T, reaching down to within a very short distance of the surface of the sample, which should rest on a flat clay-tile, reaching about half-way up, as shown by the dotted line. The temperature is first raised to 132° (270° F.), the sample is placed in the oven, and the dampers are carefully adjusted, so that this temperature can be kept constant for one hour. A Bunsen's burner is a convenient method of heating. No stickiness should be perceptible with a perfectly cured sample, when, after heating, it has cooled down to the temperature of the air.

As petroleum acts energetically on vulcanized rubber, steam-valves for marine and other engines have become specialties with the leading indiarubber manufacturers. The distention produced by these mineral oils at 100° (212° F.) affords a ready test for the suitability of a compound for steam-valves; a good valve should remain firm, and swell slightly, after several hours.

Efflorescent sulphur is removed from the surface of vulcanized goods by boiling for some time in a strong aqueous solution of caustic soda. Fabrics are washed over with the same solution, and well dried. Carbon bisulphide can be used for this same purpose. The boiling process is called "devulcanizing," but more correctly is desulphurizing. Deodorizing is effected by exposing the goods to air and charcoal; bleaching is rapidly performed by exposure to sunlight in the open air.

859.



Pigments.—A manufacturer should know whether his pigments are what they are represented to be. The following simple tests will answer generally for the more important:—

Sublimed or flowers of sulphur, stirred into distilled water, should only slightly redden litmus-paper, as sulphurous acid modifies the action in curing. It should entirely disappear when heated, and should readily yield about 60–70 per cent. of its weight to bisulphide of carbon. Ground sulphur has been lately introduced as a substitute for the above. It agrees with it, except in that it entirely dissolves in a little bisulphide of carbon. It should be a more acceptable agent for curing than the preceding. Milk of sulphur should entirely dissolve in bisulphide of carbon, and disappear when heated in a porcelain dish.

Sulphide of antimony is readily soluble in sulphide of ammonium. A solution of tartaric acid should take up only a small proportion of soluble salts or oxides, which are precipitable by sulphuretted hydrogen from this solution for estimation. Bisulphide of carbon should remove 25–40 per cent. of sulphur, and leave a perfectly bright-red residue.

Oxide of zinc, shaken up in a test-tube with sulphide of ammonium, should be only slightly darkened by traces of lead and iron. A slight insoluble residue (silica, sulphate of lead, &c.) should remain after treatment with dilute sulphuric acid. The filtered solution, neutralized with ammonia, and the same added in excess, and left in a warm room for some time, should show only a slight deposit of hydrated sesquioxide of iron. The filtered solution, strongly acidified with nitric acid, treated with solution of molybdate of ammonia, and allowed to remain in a warm place for 24 hours, should yield only a very slight yellow precipitate, due to arsenic.

White-lead and litharge, if pure, dissolve readily in nitric acid. Commercial litharge yields an insoluble residue (fine sand, &c.) of 17–18 per cent. Insoluble matters in white-lead ought to be insignificant. It is sometimes adulterated with sulphates of lime and baryta. The nitric acid solution, submitted to the action of sulphuretted hydrogen for a long time, and the clear portion evaporated, should show but a very slight residue, principally iron.

Red-lead, digested for a short time with fuming nitric acid, and then largely diluted with water, should dissolve easily. The solution, treated as above, should give little or no residue when the liquid filtered off is evaporated. It is not so largely adulterated as has been stated.

Caustic lime should effervesce but slightly with hydrochloric acid, and should leave a small quantity of undissolved matter (silica and small pieces of flint). Hydrated carbonate of magnesia is entirely soluble in dilute sulphuric acid; lime, if present, should not exceed 1–2 per cent. The loss due to carbonic acid is about 33 per cent., and to water, 30 per cent. (see Acid—Carbonic).

To test for moisture, a weighed quantity of the substance is placed in a desiccator for about 24 hours. The sulphuric acid in the dish absorbs the moisture, and the sample is reweighed. Moisture in pigments is a source of serious trouble, consequently everything should be well dried, and kept free from damp. As sulphur oxidizes on exposure to the air, especially in a warm place, it should be kept well covered up when sifted.

The pigments which are incorporated with rubber and sulphur have different effects, as they may retard or assist the vulcanizing. Red-lead and white-lead assist the curing, probably by forming sulphurous acid when heated with the sulphur, or by giving up their oxygen to the rubber. They are converted into sulphides by curing. Caustic lime and magnesia (hydrates) have an accelerating influence, when used in small quantities; in larger quantities, lime will yield hard compounds at much lower temperatures, and in shorter time for curing, than if sulphur alone had been used; these substances are probably converted into sulphides, for when a piece of this rubber is broken, and slightly moistened with an acid, distinct traces of sulphuretted hydrogen are perceptible. Carbonates of lime (whiting) and magnesia (hydrated carbonate) do not behave in this way. Magnesia hardens the rubber, by its absorptive properties; and the same may be said of French chalk, baryta, and similar pigments. Oxide of zinc retards the curing; it is not certain whether it is converted into sulphide, although rubbers containing much oxide of zinc require more sulphur

If the oxygen were liberated in the same way as with lead oxides, or caustic lime, a similar result might be expected; this not being the case, it is possible that if a sulphur acid be formed, it is taken up by the zinc.

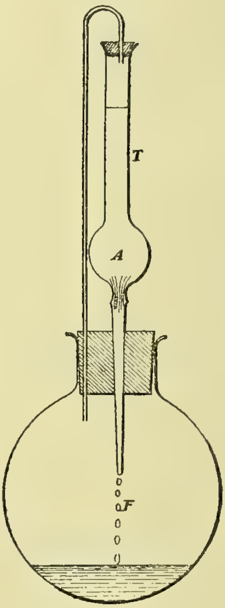
It is said that metallic sulphides will cure in the same way as sulphur. This admits of easy contradiction, for if the sulphides of antimony, arsenic, lead, and zinc, be deprived of their free sulphur, no curative action is visible. The presence of chloride of arsenic in sulphide of arsenic containing no free sulphur will explain the curing action of this pigment. Sulphide of zinc does not retard the vulcanizing action, like the oxide does; and goods containing this pigment retain a purer white colour.

For the purpose of colouring, only those metallic compounds can be used whose metals yield sulphides of suitable colour, or which are not easily converted into sulphides from the combination which is employed. Oxide of chromium yields green; sulphide of antimony, red; of mercury, crimson; of arsenic, yellow; of cadmium, yellow; of zinc, white; of lead, black. Spanish brown, and other mineral silicates which are not easily decomposed by strong acids, can likewise be used as colouring matters. Blacks are also obtained with lamp-black, vegetable-black, and graphite. The sulphides of tin have not been used, although they are very permanent.

The amount of sulphur absolutely necessary to vulcanize any particular class of goods depends upon the uses to which they are to be applied. From 1½ to 2 per cent. of sulphur will, with a heat of 138° (280° F.) for 2 hours, and ½ hour for getting up the heat, cure Pará rubber perfectly, provided that the mixture is not overworked or ground too much. Vulcanized rubber used for mechanical work contains 5–7 per cent. of sulphur; ebonite, and hard goods, 30–50 per cent. Where small quantities of sulphur are required, it is better to use precipitated or milk of sulphur; it is more easily soluble in the naphtha for spreading, and thus becomes more evenly distributed. The sulphides of antimony and lead contain their free sulphur in this form. The proportions used are equivalent to adding 2–5 per cent. of sulphur to the rubber.

The quantity of free sulphur in these compounds is readily ascertained by percolation in a filter-tube with carbon bisulphide. A filter-tube T, Fig. 860, is plugged with a little asbestos A in long fibres; any loose particles are removed by pouring in some bisulphide; a weighed quantity of the sulphide is placed in the tube, sufficient bisulphide is poured over it to moisten it, and after a few drops have passed through into the flask F, the filter should be filled up, and the tubes connected as shown. The flask is fitted with a cork containing two perforations, one for the filter-tube, the other for a bent glass tube, which passes into a cork at the top of the filter; in this way, the exhaustion goes on out of contact with the air. The flask should be carefully dried and tared. After the sulphur has all passed into the flask, the latter is fitted with a bent tube, and placed in a beaker of hot water, so as to drive off the carbon bisulphide into a cool receiver, connected with a suitable condenser. The weight of sulphur is determined by reweighing the flask. Carbon bisulphide should always be evaporated by means of warm water, and out of contact with flame.

860.



Moulding, &c.—Few shaped articles can be cured with certainty without some support. Compounds which are sufficiently firm to retain their shape tolerably well, when heated, are simply imbedded in French chalk; most articles, however, are cured in moulds, either of iron or of brass, having the exact size and form of the required article. For solid goods, the rubber is forced into the moulds under pressure, which is kept up until they are cured. Hollow goods are placed in the moulds in segments, which are joined together, and before being closed up, a little water or carbonate of ammonia is introduced; the article is then placed in its proper mould, clamped, &c., ready for curing. The water or ammonia expands during the heating, and causes the rubber to completely fill up the mould. Buffers, springs, and washers, are moulded in long cylindrical iron moulds, accurately turned inside; a spindle passing through the centre forms the required hole, and serves to clamp the ends of the moulds tightly together; when cured, the springs are removed from the moulds, and cut up in a lathe into washers, or any desired thickness of buffers. An unsoiled thin calendered sheet is sometimes rolled up on a spindle or mandril, taking care to exclude all air from the folds, and rolling evenly on a hard surface; a binding of cloth is applied as tightly as possible, which serves as a mould in curing. Small washers or rings are cut from these in the same way as buffers, a wooden mandril or spindle being passed through the central hole formed by the wire or rod on which the sheet has been rolled. Small articles are conveniently formed by repeatedly dipping moulds or forms into a solution of indiarubber, and drying after each immersion, until the required thickness has been given to the article.

Mats are formed by perforating the calendered sheet by punches, so as to give the required device; the design is first stencilled in chalk or whiting on the sheet, the parts are removed so as to leave the design or pattern, when it is cured in French chalk.

Compressed paper-pulp, plaster of Paris, and vulcanized rubber itself are frequently employed for moulds in curing. Vulcanite sheets are cured between sheets of pure tin-foil, smeared over with lard-oil, or, to avoid soiling with metal, sometimes between sheets of hard cured rubber.

The plies of belting, hose, hemp or rope packing, &c., are put together by manual labour; each ply is well rolled down by pressure. Corrugated rollers are sometimes used to give rough surfaces to washed or calendered sheets of rubber. Rubber compounds are frequently calendered on fabrics which are cured with the goods, and stripped off afterwards. This stripping is facilitated by well damping the cloth with water; if this is ineffectual, a little naphtha should be applied after thoroughly drying off the water. In such cases, the fabric itself forms the mould by keeping the article in shape. Telegraph-wire is kept cylindrical by a lapping of felt or other fabric.

A very convenient metal or alloy for moulds or shapes is a mixture of tin and lead, which can be recast with trifling loss for any altered design. The stain left by iron moulds can be removed by dilute sulphuric acid.

Dipping forms or moulds into solutions of rubber, and allowing the solvent to evaporate, is a very convenient way of obtaining many small articles, which are required to be seamless and smooth; the mould is removed either before or after the article is vulcanized.

Vulcanite is stamped into various forms or devices by cutting-dies; the hard cured material is made warm before being placed in the press; the dies are made of well tempered steel. Combs and similar articles are stamped out by cutting-dies in the same way. Tubing or sheet can be readily bent to any required form, when heated over a gas-jet, until it becomes soft. In a lathe, vulcanite admits of being turned or worked like wood or metal. It is polished by means of a cloth buff, running at about 800 rev. a minute, with brick-dust and oil. Vulcanite is used for insulators for aërial lines of telegraph, cells for galvanic batteries, photographic baths, &c. Battery cells and insulators are tested electrically by being filled with water, slightly acidulated with sulphuric acid. Vulcanite has almost entirely replaced glass for frictional electric machines. With the ordinary silk rubber, it yields negative electricity.

The principal articles made from soft rubber are valves, springs, buffers, washers, tubing, packing, and telegraph-wire; spread on cloth, it is largely used for pontoons, garments, balloons, diving-dresses, sheeting, garden-hose, canvas packing, belting, invalid mattresses, &c. From hard rubber or ebonite, acid-pumps, battery cells, insulators, tubing, rod, sheet, photographic, surgical and sundry vessels for holding chemical liquids. Kamptulicon is manufactured by incorporating cork-dust with waste rubber (see Floorcloth—Kamptulicon).

Reworking Rubber Compounds.—For some years past, indiarubber manufacturers have endeavoured to utilize the parings of vulcanized rubber, old valves, packing, &c. So inferior is the product, that it is only suitable for very low-class goods; hence it is that old vulcanized rubber realizes such a small price compared with the new article. Numerous patents have been devoted to the object, such as grinding with water, naphtha, caustic alkalies, acids, &c. Generally the rubber is ground dry between a strong pair of grinding-rolls. Ground waste being liable to spontaneous combustion, it should be carefully watched, and kept in a cool place. A short time ago, it was much used for stuffing chairs, &c. Numerous cheap articles are now made from ground waste, by agglutinating with dough or solution, compressing, and curing. Compounds containing ground waste cure more readily than fresh rubber. In purchasing rubber for reworking, it is difficult to give any very definite tests as to its value. Most manufacturers mark their goods, which is of great use in selecting old valves, buffers, &c. Hose-cuttings and belting, before being cured, are ground up together, and are very useful for packing, to withstand attrition or other rough treatment. As woollen cuttings cause blisters and sponginess, care must be taken to separate them from cotton cuttings, by sorting, or by boiling in caustic alkalies when the fabrics are mixtures of wool and cotton, or silk and cotton. Forster and Heartfield proposed the use of wool for indiarubber sponge. By heating, the wool is easily charred, and the moisture or gases generated give the rubber a honeycombed structure.

When vulcanized rubber is strongly heated in a closed vessel under pressure for some hours, and the liquids produced by its decomposition are distilled off by superheated steam, or removed by compression, a soft mass is obtained suitable for incorporating with fresh rubber. Vulcanite waste is reworked by being finely ground, when it can be incorporated with fresh uncured material. When thoroughly cured, it cannot be jointed nor repaired; but if slightly cured, adhesion between it and new material can be successfully secured. Hence large masses should never be cured thoroughly in the first heating.

Rubber Substitutes.—Under the name of "artificial rubber," several compounds have been introduced with more or less success. The basis of the most important are oxidized and vulcanized oils (see Floorcloth; Oils). Lake's "improved artificial indiarubber compound" consists of saponified resins and vulcanized oils, which are incorporated with indiarubber or guttapercha, and vulcanized in the usual way. In Day's "improved substitute for indiarubber," the oils are partially saponified by acids, and are then heated with sulphur, &c. These acid compounds cannot be used in the manufacture of fabrics, as the heating would destroy the fibre. Bruce Warren's "thionoline" or vulcanized oil consists of linseed-oil, or other drying oils, vulcanized by adding sulphur at high temperatures. Oils vulcanized by chloride of sulphur are obtained by treating similar oils with chlorinated sulphur, or sulphur chlorides; the principal objection to these compounds is their acid qualities, which prevent their being used with fabrics, or certain pigments. Leather parings and wool have been proposed as substitutes, when previously treated with chloride of sulphur, or heated in molten sulphur. Oxidized oils have also been proposed, but have not been so successfully employed. A material called "vulcanized fibre" has lately been introduced. It consists of animal or vegetable fibre, paper-pulp, &c., mixed with vulcanized oil and glycerine, and calendered or spread by some such arrangement as Clark's machine, shown in Fig. 849, p. 1148.

Guttapercha in many of its properties agrees with indiarubber, and is manufactured for some of the same purposes. At 100° (212° F.), it is soft and plastic, but regains its firmness on cooling. By destructive distillation, it yields oily hydrocarbons. It is soluble in the same menstrua as indiarubber. It is cleansed or freed from its impurities first by slicing into very thin laminæ, being forced against a revolving wheel or disc, furnished with radial knives or blades. These parings are thrown into cold water, when the heavier impurities sink; the floating portions are passed on to another tank, containing boiling water; in this, it is softened by boiling, so as to allow sand, particles of wood, &c., to separate out; it is then collected in a machine called a "ticker" or "teazer," in which it is still further torn up in warm water. According to the class of goods required, this operation is carried to a greater or less extent. It is then, worked in a closed masticator for some hours with hot water, kept warm by injected steam; and is finished off in another masticator, first heated by steam, to expel all traces of moisture. Whilst plastic, it is strained through very fine wire gauze, by means of hydraulic pressure. The portion of the press holding the guttapercha is jacketed, so as to admit of being kept quite hot by steam or hot water. For stowing away, it is not kept in blocks or masses, like indiarubber, but is calendered into sheets about $\frac{3}{8}$ in. thick. Calendered into very thin sheet, it is largely used for surgical purposes, and for protecting goods against damp. Machine-bands, cord, tubing, buckets, and tanks for electro-plating, are the principal articles manufactured, except cores for telegraph purposes, for which it is eminently adapted. For this purpose, however, the raw article is carefully selected.

Articles are moulded from guttapercha, by working it by hand, whilst in a soft and plastic state, into the required form; it needs very careful, though not skilful, labour; to prevent it sticking to the hands or fingers, they should be wetted with water containing a little soap, taking care to remove all traces of moisture when jointing is required. It is kept soft in water heated by steam. Picture-frames and similar articles are made in metallic moulds. Cord, tubing, and telegraph-wire, are made by forcing the plastic material through dies of special construction, from which the articles traverse a long tank of cool water. To increase the cooling action, telegraph-wire is passed backwards and forwards several times. The moisture must be removed before another coating can be applied. Telegraph-wire is carefully overhauled after each coating, and any defect is cut out or repaired by an operation called "tooling." A heated iron is applied to the guttapercha, and is carefully moved about, so as to work it well together over the defective part. The wire, or as it is now called, "the core," is passed first through a heated mixture of guttapercha, rosin, and Stockholm tar, and then through the dies, to receive a second coating of guttapercha. When cooled, the overhauling, and coating with compound and guttapercha, are repeated, according to the number of coatings required. This series of coatings secures the centrality of the conducting-wires, a greater freedom from faults, and rapidity of cooling. Although the application of the required guttapercha at one operation would save great cost of labour, it is not adopted. The copper wires are first coated with the compound, immediately before applying the guttapercha; or, if stranded wires are used, the central one is drawn through the compound, when the other wires squeeze the compound into the interstices of the strand, and fill them up completely. This compound serves to unite all the coatings together, and to the conducting-wires. At one time it was proposed to place the completed core in an iron tank, and after exhausting the air as far as practicable, to force in this compound, or Stockholm tar alone, under great pressure, so as to fill up any cavities or pores. This has led to the present improved condition of telegraph-wire.

Specifications for guttapercha telegraph-wire stipulate that certain electrical and mechanical data shall be carried out. The copper, whether solid or stranded wires, must weigh so much per statute mile for land work, or so much per nautical mile for cable or submarine work; and the specific conductivity of the copper must be equal to (within a small percentage) that of pure copper. The guttapercha must be applied in several coatings, alternating with a coating of compound.

The wire or strands are to be filled up or coated with the same compound. The completed core is tested electrically after being kept in water at a temperature of 24° (75° F.) for 24 hours. As these wires are electrically better after a short time than when newly made, it is necessary to keep the core, if possible, for a fortnight or longer before testing.

Telegraph-cores are made into cables, coated with lead, and sometimes taped and tarred for street or tunnel work, when they are afterwards drawn through sand. For military purposes they are braided, and saturated with a mixture of beeswax, rosin, &c. Joints in telegraph-wire are made in the following manner. The conductor, well cleaned, is first soldered up, and the guttapercha is softened by the flame from a spirit-lamp, and worked uniformly backwards from the joint. The exposed wire is coated with compound, and the guttapercha is carefully worked from both sides of the joint towards the middle, where the blending should be perfect. A coating of warm compound is applied over this, and one or more layers of specially prepared guttapercha sheet are worked over with alternate coatings of compound.

Sabine gives the following method for making joints in guttapercha cores. The two ends to be joined together are first cut "flush," so that each end presents a clear section. The guttapercha is next warmed for a distance of 3 in. by a spirit-lamp (in which wood-naphtha is burned), and when softened, is worked or rolled back into a knob; the conductor is joined, and smeared with a coating of Chatterton's compound (described below); one knob is warmed, and worked gradually towards the other, so as to form a tubular covering; this is smeared with another coating of compound; the other knob is softened, and worked down over it towards the other end, so that two tubes are formed, one from each end, and overlapping each other. Another coating of compound is applied, and, over this, a piece of softened joint-sheet is evenly and carefully worked. The whole is "tooled" up with a heated iron, so as to make a perfectly homogeneous covering. Sometimes the two knobs are worked simultaneously towards the middle, the excess of guttapercha is removed, so as to ensure only a thin but perfect covering, and the full diameter of the core is made up with new sheet and compound alternately.

A rough kind of joint is made by enclosing the two ends in a tube of glass or metal, which is moved on one side so as to join the conductor; this is smeared with compound, or a mixture of ozokerit, &c.; the tube is drawn over the joint, and filled in with similar compound. Willoughby Smith places the completed joint in a grooved piece of wood, and secures on it a similar grooved piece so as to compress the joint. Warren recommends a longitudinal strip of canvas, wrapped with a spiral covering of cotton tape. For temporary joints in indiarubber wires, Warren proposes a vulcanized indiarubber tube, drawn over the wire, and secured at the ends with twine. Cotton-tape soaked in paraffin, or strips of vulcanized rubber, lapped tightly on with alternate smearings of compound, make very useful temporary joints.

Joints in telegraph-cores are tested electrically. After immersion in water for some hours, they should be quite firm and hard, smooth and regular, and only a trifle larger than the core itself. Rapid cooling is dangerous, as unequal contraction might lead to "stripping" or non-adhesion in the coatings.

Jointing-sheet is a specially prepared guttapercha, having a dark colour, about ⅛ in. thick; it is a little more highly worked than for ordinary purposes, and becomes more adhesive when heated. It should be kept in air-tight cases in a cool place; it should be rejected when the surface has a brittle or resinous appearance, cracking slightly when bent or folded.

Chatterton and Smith propose to immerse guttapercha cores in Stockholm tar, with a view to render them more repellent. The cores are placed in a closed tank, and the air is pumped out, so as to obtain a vacuum. The tar, heated to 21°–27° (70°–80° F.), is run in by opening a stopcock communicating with the reservoir; a pressure of 500 lb. a sq. in. is then put on for 10 minutes. Reid's pressure-tanks were much used for testing cores under pressure and vacuum. The cores, if air were enclosed between the coatings, showed a rough and irregular surface by the vacuum test; and holes, imperfect jointing, and impurities, were rendered more evident by the injection of water, which was afterwards pressed to 500–1000 lb. a sq. in., according to the depth for which the cable was required. Small hydraulic pumps, on the same principle, were used for testing guttapercha joints.

Willougby Smith's improved guttapercha has of late been very extensively employed for telegraph cable-cores. It possesses remarkable electrical advantages. Anthracene is said to reduce the inductive capacity of guttapercha; its use as an insulator has been patented by Perkins and Tandy.

Vulcanized Guttapercha.—Some years ago it was proposed to cure guttapercha by adding sulphur to it in the masticating-machine. Large quantities of telegraph-wire were made with this mixture; but as the sulphur was not combined, it so corroded the copper wire, that in a few years it became entirely converted into sulphide. This fact gave rise to the discovery of Statham's fuzes. If guttapercha be mixed with indiarubber, and sulphur be added to the mixture, it can be readily vulcanized, either to a soft or hard state. Guttapercha can be vulcanized by the cold-curing process. The cleansed guttapercha is cut up into shreds, and dissolved in carbon bisulphide, so as to form a stiff solution; to this solution, 2–15 per cent. of chloride of sulphur is added, according to the required extent of vulcanizing: 10 per cent. renders the guttapercha hard and horny, and not softened at 100° (212° F.). Sheets are vulcanized by repeated dipping. Parkes adopted the use of curing agents in vapour and solution. Guttapercha thus treated has not received much attention, although it possesses many remarkable qualities, and may be moulded, whilst liquid or plastic, into any form; being colourless, or nearly so, it might replace ivory in many of its applications. It might also be used for chemical-tanks, pipes, &c., as it is not softened by heat, nor acted upon by cold acids or alkalies. Bromine, chlorine, and phosphorus, and their sulphur compounds, have also been proposed for this purpose; the chlorides of sulphur are the best and cheapest.

Cattell's bleached guttapercha is made by dissolving cleansed guttapercha in solvents requiring heat, as coal-tar naphtha, and its rectified products, turpentine, and rosin-spirit; or solvents requiring no heating, as chloroform, and carbon bisulphide. In using the first class of solvents, 1 oz. of alcohol, holding in solution 30 drops of glycerine to the gallon (soap, wood-naphtha, or commercial nitrate of ethyl, may be used in the same proportions), is agitated in a closed vessel, together with the solvent and guttapercha, for an hour or more, until sufficiently defecated or decolorized, when it is decanted, and mixed with a little alcohol and glycerine, to precipitate the guttapercha. The solvent is recovered by distillation. The alcohol or similar agent removes the oxidized portions of the guttapercha, resins, &c., and leaves the pure guttapercha colourless.

Articles manufactured of guttapercha rapidly become brown on exposure to the air, from oxidation, and are ultimately converted into a brittle resinous matter. This is prevented to a great extent by varnishing with shellac dissolved in wood-spirit. In manipulating guttapercha, manufacturers avoid bringing into contact with it, any liquid or substance having a solvent action, such as coal-tar naphtha. The incorporation of Stockholm tar tends to preserve guttapercha, and there is no doubt that many resinous substances can be blended with it in presence of this tar, which could scarcely be safe without it, from their setting up some kind of decomposition, which is not easily explained.

Cattell's purified guttapercha can be mixed with colouring pigments, for the production of useful or ornamental objects. Oxide of zinc, vermilion, and similar compounds, can be used; but not oxides or compounds which represent a saturated or high degree of oxidation. Guttapercha, by strong oxidation, gives rise to formic acid. As guttapercha resists the action of fluoric acid, it is made into bottles, jars, &c., for holding this corrosive liquid. Silver salts and cyanides generally are decomposed in contact with guttapercha, consequently this substance is not suited for tanks to contain these liquids; but if the surface be well brushed over with graphite, the action of these bodies may be retarded.

Chatterton's Compound.—This compound is employed for uniting the different coatings of guttapercha cores, and for cementing guttapercha to wood, &c. It is sold in rolls about 1 in. thick, and 7–8 in. long. It should soften readily at 38° (100° F.), and become firm again when cooled for a few minutes. Its freshly cut surface should be smooth and compact; it should not break, but bend easily with slight elasticity; its sp. gr. is about 1·020, it should not become hard or brittle on exposure to the air. The following process is adopted for its manufacture—$\frac{1}{5}$ by weight Stockholm tar, and about the same weight of rosin, are put into a jacketed vessel, heated by steam, strained when melted, and intimately mixed with $\frac{3}{5}$ by weight of cleansed guttapercha in shreds or thin pieces. The whole is worked together by horizontal stirrers, fixed on a vertical shaft.

There are a few other substances having intermediate properties between indiarubber and guttapercha, such as "balata," a product obtained from the "bullet-tree" of British Guiana, "susu-poco," and "chapapote." Balata closely approaches guttapercha, and is used in many of its manufactures. The inspissated juice of the "cow-tree" (*Massaranduba*) has been for the last few years exported from Pará as indiarubber. Warren has shown that it is quite equal to the finest descriptions of Pará rubber, when vulcanized.

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(See Resinous Substances.)

INK (Fr., *Encre* ; Ger., *Tinte, Dinte*).

The term "ink" is used to denominate a great variety of fluid or semi-fluid compounds employed in the permanent delineation of objects upon paper, stone and other grounds. The chief desiderata in most inks are a capacity of flowing readily from the writing instrument, while possessing sufficient body to prevent spreading and blotching, combined with a depth and permanency of colour. The latter naturally depends in a great measure upon the physical and chemical characters of the article written upon, and especially upon the presence or absence of bleaching agents. The composition of inks varies as widely as do the purposes to which they are applied; hence they may be classified as follows:—Black writing-ink, copying-ink, coloured writing-ink, invisible or sympathetic ink, marking-ink, Indian-ink, printing-ink, engraving-ink, ink for stone or marble-writing, and gold and silver inks.

Black Writing-ink.—The following are among the most approved recipes:—

A. With Galls and Sulphate of Iron.—(*a*) 1 lb. bruised galls, 1 gal. boiling water, 5⅓ oz. sulphate of iron (copperas) in solution, 3 oz. gum arabic previously dissolved, and a few drops of an antiseptic, such as carbolic acid. Macerate the galls for 24 hours, strain the infusion, and add the other ingredients. (*b*) 12 oz. bruised galls macerated for a week in 1 gal. cold water, 6 oz. sulphate of iron in solution, 6 oz. mucilage of gum arabic, and a few drops of antiseptic. (*c*) 12 lb. bruised galls, boiled for an hour in 6 gal. soft water, adding water to replace that evaporated; strain, and reboil the galls in 4 gal. more water for ½ hour; strain, and boil with 2½ gal. more water; strain, and mix the liquors. Add 4½ lb. coarsely powdered sulphate of iron, and 4 lb. gum arabic in small pieces; agitate till the ingredients are dissolved, and filter through a hair sieve. This will make about 12 gal. of good ink. (*d*) 2 lb. bruised galls, digested in 2 qt. alcohol at a temperature of 40°–60° (104°–140° F.); when about half the alcohol has evaporated, add 3 qt. water; stir well, and strain through a linen cloth. To clarify the solution, add 8 oz. glycerine, 8 oz. gum arabic, and 1 lb. sulphate of iron dissolved in water. Stir thoroughly from time to time for a few days, allow to settle, and put up in well-stoppered bottles for preservation. The addition of too much sulphate of iron is to be avoided, as causing the ink soon to turn yellow. Ink thus prepared is said to resist the action of light and air for at least 12 months, without suffering any change of colour. (*e*) Digest in an open vessel 42 oz. coarsely powdered galls, 15 oz. gum senegal, 18 oz. sulphate of iron, 3 dr. aqua ammonia, 24 oz. alcohol, and 18 qt. distilled or rain water. Continue the digestion till the fluid has assumed a deep black colour. (*f*) To good gall ink, add a strong solution of fine Prussian blue in distilled water; the ink writes greenish-blue, but afterwards turns black; it is said that it cannot be erased either by acids or alkalies, without the destruction of the paper. In all the inks described in this section, nut-galls are introduced for the sake of their tannic acid. For this purpose, they are not equalled by any other tannin-yielding substance; and a Commission lately appointed by the Prussian Government, to decide what was the best ink to be employed for official purposes, selected that made from galls as being the foremost of all for durability. For cheaper inks, the galls may be replaced by catechu, sumach, and the host of other astringent substances described in the article on Tannin. The antiseptic (carbolic acid, &c.) is added to prevent the formation of mould.

B. With Logwood.—(*a*) A decoction of logwood is first made by boiling 10 lb. logwood in enough water to produce 80 lb. of the decoction. To 1000 parts of this logwood extract, when cold, is added 1 part of yellow (neutral) chromate of potash (K_2CrO_4), stirring rapidly. It is ready for use at once, without any addition; but it possesses the great fault of soon becoming thick. This may be corrected by (*b*) adding corrosive sublimate, or any other antiseptic. (*c*) Boil 10 oz. logwood in 20 oz. water; then boil again in 20 oz. more water, and mix the two decoctions; add 2 oz. chrome alum, and boil again for ¼ hour; add 1 oz gum arabic. The product is 25 oz. deep black ink. (*d*) Dissolve 15 parts extract of logwood in 1000 parts distilled water, to which 4 parts carbonate of soda have been added at boiling heat; and add 1 part neutral chromate of potash dissolved in a little water. This ink will not gelatinize. (*e*) 10 lb. best logwood is repeatedly boiled in 10 gal. water, straining each time. The liquid is evaporated down till it weighs 100 lb., and is then allowed to boil in a pan of stoneware or enamel. To the boiling liquid, nitrate of oxide of chrome is added in small quantities, until the bronze-coloured precipitate formed at first is redissolved with a deep blue coloration. This solution is then evaporated in a water-bath down to a syrup, with which is mixed well-kneaded clay in the proportion of 1 part of clay to 3½ of extract. A little gum tragacanth is also added to obtain a proper consistence. It is absolutely necessary to use the chrome salt in the right proportion. An excess gives a disagreeable appearance to the writing; while, if too little is used, the black matter is not sufficiently soluble. The other chrome salts cannot be used in this preparation, as they would crystallize, and the writing would scale off as it dried. The nitrate of oxide of chrome is prepared by precipitating a hot solution of chrome alum with carbonate of soda. The precipitate is washed till the filtrate is free from sulphuric acid. The precipitate thus obtained is dissolved in pure nitric acid, so as to leave a little still undissolved. Hence the solution contains no free acid, which would give the ink a dirty-red colour.

Oxalic acid and caustic alkalies do not attack the writing. Dilute nitric acid reddens, but does not obliterate the characters. This ink is manufactured into ink-pencils, which give a very black writing, capable of reproduction in the copying-press, and not fading on exposure to light. (*f*) 20 parts by weight extract of logwood are dissolved in 200 parts water, and the solution is clarified by subsidence and decantation. A yellowish-brown liquid is thus obtained. In another vessel, 10 parts ammonia alum are dissolved in 20 parts boiling water; the two solutions are mixed, there being also added $\frac{1}{5}$ part sulphuric acid, and finally $1\frac{1}{2}$ part sulphate of copper. The ink should be exposed to the air for a few days to give it good colour, after which, it should be stored in well-corked bottles. (*g*) 30 parts extract of logwood are dissolved in 250 parts water; 8 parts crystallized carbonate of soda, and 30 parts glycerine (sp. gr. 1·25), are added; lastly, 1 part neutral chromate of potash and 8 parts gum arabic, reduced to a powder, and dissolved in water. This ink does not attack pens, does not turn mouldy, and is very black.

C. MISCELLANEOUS.—(*a*) The juice or sap of the ink-plant of New Granada, to which is given the name of *chanhi*, is at first of a reddish tint, but in a few hours becomes intensely black. It may be used without any preparation. The *chanhi* corrodes steel pens less than ordinary ink, and better resists the action of time and chemical agents. It is said that, during the Spanish rule, all public documents were required to be written with this ink: written otherwise, they were liable to damage by sea-water. (*b*) 20 gr. sugar is dissolved in 30 gr. water, and a few drops concentrated sulphuric acid are added; the mixture is heated, when the sugar is carbonized by the acid.

Copying-ink.—The quality required of a copying-ink is that it shall afford one or more copies of the written matter by applying dry or damped paper to its surface, and subjecting it to more or less pressure. The best kinds of copying-ink are usually prepared by adding a little alum to an extract of logwood of 10° B. (1·075 sp. gr.), or to a decoction of the same, and then, to improve its copying power, some sugar and glycerine, or table-salt is added. Such inks have a violet tint, are purple when first written, and gradually darken on the paper. The copies taken from them are at first very pale, and only slowly darken. The chief recipes for copying-inks are the following:—(*a*) Mix about 3 pints of jet-black writing-ink and 1 pint glycerine. This, if used on glazed paper, will not dry for hours, and will yield one or two fair, neat, dry copies, by simple pressure of the hand, in any good letter copy-book. The writing should not be excessively fine, nor the strokes uneven or heavy. To prevent "setting-off," the leaves after copying should be removed by blotting-paper. The copies and the originals are neater than when water is used. (*b*) A good copying-ink may be made from common violet writing-ink, by the addition of 6 parts glycerine to 8 parts of the ink. Using only 5 parts of glycerine to 8 of the ink, the ink will copy well 15 minutes after it has been used. With fine white copying-paper, it will copy well without the use of a press. (*c*) $\frac{1}{2}$ lb. extract of logwood, 2 oz. alum, 4 dr. blue vitriol (sulphate of copper), 4 dr. green vitriol (sulphate of iron), 1 oz. sugar; boil these ingredients with 4 pints water, filter the decoction through flannel; add a solution of 4 dr. neutral chromate of potash in 4 oz. water, and a solution of 2 oz. "chemick blue" in 2 oz. glycerine. The "chemick blue" is the solution of indigo in sulphuric acid, or sulphindigotic acid. (*d*) A black coyping-ink, which flows easily from the pen, and will give very sharp copies without the aid of a press, can be prepared thus:—1 oz. coarsely broken extract of logwood, and 2 dr. crystallized carbonate of soda, are placed in a porcelain capsule with 8 oz. distilled water, and heated until the solution is of a deep-red colour, and all the extract is dissolved. The capsule is then taken from the fire. Stir well into the mixture 1 oz. glycerine, (sp. gr. 1·25), 15 gr. neutral chromate of potash, dissolved in a little water, and 2 dr. finely pulverized gum arabic, which may be previously dissolved in a little hot water so as to produce a mucilaginous solution. The ink is now complete and ready for use. In well closed bottles, it may be kept for a long time without getting mouldy, and, however old it may be, will allow copies of writing to be taken without the aid of a press. It does not attack steel pens. This ink cannot be used with a copying-press. Its impression is taken on thin, moistened copying-paper, at the back of which is placed a sheet of writing-paper. (*e*) A new kind of Parisian copying-ink has been recently introduced into Germany, which differs from those previously in use in having, while liquid, a more or less yellowish-red colour; but on paper, it rapidly turns blue, and immediately produces a distinct blue-black copying-ink. Moreover, it remains liquid a long time, while ordinary violet copying-ink soon gets thick; this kind copies easily and perfectly. The following is the method of its manufacture:—A logwood extract of 10° B. (sp. gr., 1·075) has added to it 1 per cent. of alum, and then enough lime-water to form a permanent precipitate. This mass is then treated with a few drops of a dilute solution of chloride of lime (bleaching powder), just enough being added to impart to it a distinct blue-black colour, after which, dilute hydrochloric acid is added drop by drop, until a distinctly red-coloured solution is produced. To this solution is added a little gum, and $\frac{1}{2}$–$1\frac{1}{2}$ per cent. of glycerine. It is evident that the small quantity of chloride of calcium, formed by this process, greatly increases the copying power of the ink; while the exceedingly slight excess of free hydrochloric acid causes the ink to remain liquid, by holding in solution the lime and alumina lakes of logwood. When the writing dries, the acid gradually escapes, or is neutralized by the trace of alkali in the paper, so that the blue-black lake is left. It is evident that any considerable excess of hydrochloric acid must be avoided, as also the use of too much chloride of lime solution. (*f*) Add 1 oz. lump-sugar or sugar-candy to 1½ pint good black ink; dissolve. (*g*) A decoction of Brazil wood and glycerine used as an ink requires neither press nor copying-paper for multiplying the impressions; it is only necessary to lay tissue-paper upon the writing, and to rub with the finger. (*h*) 5½ oz. best galls, 1 dr. bruised cloves, 40 oz. cold water, 1½ oz. pure sulphate of iron, 35 minims pure sulphuric acid, ¼ oz. sulphate of indigo in thin paste, and neutral or nearly so. Place the galls, when bruised, with the cloves, in a 50-oz. bottle, pour in the water, and digest, shaking daily, for a fortnight. Filter through paper into another 50-oz. bottle. From the refuse of the galls, wring out the remaining liquor through a strong clean linen or cotton cloth into the filter, to avoid waste. Put in the iron, dissolve completely, and filter through paper. Add the acid, and agitate briskly; add the indigo, and shake up thoroughly; pass the whole through filter-paper. Filter from one bottle to another till the operation is complete. The same ingredients may be used for common writing-ink, reducing the proportion of galls to 4½ oz.

Coloured Writing-ink.—Coloured inks may be divided into two classes, those in which the colouring matter is derived from coal-tar, and those in which it is not.

A. WITHOUT COAL-TAR COLOURS.—*Red:* (*a*) 4 oz. ground Brazil wood, and 3 pints vinegar, boiled till reduced to 1½ pint, and 3 oz. powdered rock alum added. (*b*) ¼ lb. raspings of Brazil wood, infused in vinegar for 2–3 days; boil the infusion for 1 hour over a gentle fire, and filter while hot; put it again on the fire, and dissolve in it, first, ½ oz. gum arabic, then ½ oz. alum and white sugar. (*c*) Boil 2 oz. Brazil wood in 32 oz. water; strain the decoction; add ½ oz. chloride of tin, and 1 dr. powdered gum arabic; then evaporate to 16 fl. oz. (*d*) Dissolve 1 dr. carmine in ½ dr. liquid ammonia, sp. gr. 0·880; dissolve 20 gr. powdered gum arabic in 3 oz. water; mix the two solutions. (*e*) Mix 2000 parts Brazil wood, 3 salt of tin, 6 gum, and 3200 water; boil till reduced to one-half, and filter. (*f*) 2 parts Brazil wood, ½ alum, ½ cream of tartar, 16 water; boil down to one-half, and filter; add ½ part gum. (*g*) To an ammoniacal solution of cochineal, add a mixture of alum and cream of tartar, till the required tint is obtained. (*h*) Digest 1 oz. powdered cochineal in ½ pint hot water; when quite cold, add ½ pint spirit of hartshorn; macerate for a few days, then decant the clear portion. (*i*) Dissolve 20 gr. pure carmine in 3 fl. oz. liquid ammonia; add 18 gr. powdered gum.

Purple: (*a*) To a decoction of 12 parts Campeachy wood in 120 parts water, add 1 part subacetate of copper, 14 parts alum, and 4 parts gum arabic; let stand for 4–5 days. (*b*) To a strong decoction of logwood, add a little alum, or chloride of tin.

Violet: (*a*) Boil 8 oz. logwood in 3 pints water, till reduced to 1½ pint; strain, and add 1½ oz. gum, and 2½ oz. alum. (*b*) Mix 1 oz. cudbear, 1½ oz. pearlash, and 1 pint hot water; allow to stand for 12 hours; strain, and add about 2 oz. gum. If required to keep, add 1 oz. spirit of wine.

Blue: (*a*) Dissolve 2–3 oz. sulphate of indigo in 1 gal. water. (*b*) Rub together 1 oz. oxalic acid and 2 oz. fine Prussian blue, and add 1 qt. boiling water; the excess of iron in the Prussian blue must first be removed by a strong mineral acid; then wash in rain water. (*c*) 2 oz. Chinese blue, 1 qt. boiling water, 1 oz. oxalic acid; dissolve the blue in the water, and add the acid; it is ready for use at once.

Green: (*a*) Calcine acetonitrate of chrome; dissolve the green powder in sufficient water. (*b*) Dissolve sap green in very weak alum water. (*c*) 2 oz. verdigris, 1 oz. cream of tartar, ½ pint water; boil till reduced to one-half, and filter.

Green-black: Boil 15 parts bruised galls in 200 parts water for about 1 hour; strain; to the liquor, add 5 parts sulphate of iron, 4 fine iron shavings, and a solution of ½ pint powdered indigo in 3 pints sulphuric acid. This ink flows readily; it writes green, but turns black after a few days.

B. WITH COAL-TAR COLOURS.—The colouring matters derived from coal-tar may all be employed for writing purposes. These inks possess bright colours, do not precipitate their colour, and dry quickly. When dried up or thickened, they can be put right by simple dilution with water. On the other hand, they are readily destroyed by chemical reagents. They must not be used with pens which have been employed in writing with other inks. They do not require any addition of gum; but if desired, 1 part dextrine may be added to every 100 parts ink. Almost all tints may be produced by mixtures, in varying proportions, of the following principal colours:—

Red: (*a*) 1 part magenta in 150–200 parts hot water. (*b*) Dissolve 25 parts (by weight) safranine in 500 parts warm glycerine; then stir in carefully 500 parts alcohol, and 500 parts acetic acid; dilute in 9000 parts water, containing a little gum arabic in solution.

Blue: 1 part soluble blue (night blue) in 200–250 parts hot water.

Violet: 1 part violet-blue in 200 parts hot water.

Green: 1 part iodine-green in 200 parts hot water. Gives a bluish-green writing; for a lighter tint, add a little picric acid.

Yellow: 1 part picric acid in 120–140 parts water. This is not very successful.

Invisible or Sympathetic Ink.—The terms "invisible" and "sympathetic" are applied to any writing fluid which leaves no visible trace of the writing on the paper, until developed by the application of heat or chemical reagents. They have been suggested (somewhat impractically it must be owned) for use on post-cards. They are principally as follows:—(*a*) Solution of sugar of lead in pure water leaves no trace of writing when dry; the written characters held over a jet of sulphuretted hydrogen are developed of an intense black colour. (*b*) Nitrate of the deutoxide of copper in weak solution gives an invisible writing, which becomes red by heating. (*c*) Chloride of copper in very dilute solution, is invisible till heated. To make it, dissolve equal parts of blue vitriol and sal ammoniac in water. (*d*) Nitrate of nickel and chloride of nickel in weak solution form an invisible ink, which becomes green by heating, when the salt contains traces of cobalt, which usually is the case; when pure, it becomes yellow. (*e*) Chloride of cobalt in properly-diluted solution will produce a pink writing, which will disappear when thoroughly dry, become green when heated, disappear when cold, and pink again when damp. When often or strongly heated, it will at last become brown-red. (*f*) When the solution of acetate of protoxide of cobalt contains nickel or iron, the writing made by it will become green when heated; when it is pure and free from these metals, it becomes blue. (*g*) Bromide of copper gives a perfectly invisible writing, which appears very promptly by a slight heating, and disappears perfectly by cooling. To prepare it, take 1 part bromide of potassium, 1 part blue vitriol, 8 parts water. It is better also to discolour the blue vitriol with 1 part alcohol. (*h*) A drawing or writing made with a strong solution of acetate of lead becomes dark-brown by exposure to sulphide of hydrogen gas. (*i*) Writing with iodide of potash and starch becomes blue by the least trace of acid vapours in the atmosphere, or by the presence of ozone. To make it, boil starch, and add a small quantity of iodide of potassium in solution. (*j*) Sulphate of copper in very dilute solution will produce an invisible writing, which will turn light-blue by vapours of ammonia. (*k*) Soluble compounds of antimony will become red by sulphide of hydrogen vapour. (*l*) Soluble compounds of arsenic and of peroxide of tin will become yellow by the same vapour. (*m*) An acid solution of chloride of iron is diluted till the writing is invisible when dry. This writing has the remarkable property of becoming red by sulpho-cyanide vapours, and it disappears by ammonia, and may alternately be made to appear and disappear by these two vapours. (*n*) Writing executed with rice-water is invisible when dry, but the characters become blue by the application of iodine. This ink was much employed during the Indian Mutiny. (*o*) Characters written with an aqueous solution of iodide of starch disappear in about 4 weeks. (*p*) Dissolve 1 fl. oz. common oil of vitriol (sulphuric acid) in 1 pint soft water; stir well, and allow to cool. Write with a clean steel pen; when dry, the writing is invisible; held to the fire, it becomes indelibly black. (*q*) Writing executed with a clean quill pen dipped in onion or turnip juice is invisible when dry; when the paper is heated, the characters assume a brown colour.

Marking-ink.—The use of marking-ink is for writing on textile fabrics; it must therefore be proof against the action of hot water, soap, alkalies, &c. The chief recipes are:—(*a*) 20 parts potash are dissolved in boiling water, 10 parts finely cut leather-chips, and 5 parts flowers of sulphur are added, and the whole is heated in an iron kettle until it is evaporated to dryness. Then the heat is continued until the mass becomes soft, care being taken that it does not ignite. The pot is now removed from the fire, and water is added; the solution is strained, and preserved in bottles. This ink flows easily from the pen. (*b*) Triturate 1·75 grm. aniline black with 60 drops strong hydrochloric acid and 42 grm. strong alcohol. The mixture is diluted with a hot solution of 2·5 grm. gum arabic in 170 grm. water. This ink does not attack steel pens, and is destroyed neither by mineral acids nor by caustic alkalies. (*c*) Neutralize 75 gr. carbonate of ammonia with pure nitric acid, and triturate 45–60 gr. carmine with the solution. Mordant the fabric with a mixed solution of acetate of alumina and tin salt, and write upon it, when it is perfectly dry, with the ink. The characters will be of a Tyrian purple colour. (*d*) Dissolve in 60 grm. water, 8·25 grm. crystalline chloride of copper, 10·65 grm. chlorate of soda, and 5·35 grm. chloride of ammonium; dissolve 20 grm. hydrochlorate of aniline in 30 grm. distilled water, and add 20 grm. solution of gum arabic (1 part gum to 2 water), and 10 grm. glycerine; 4 parts of the aniline liquid mixed in the cold with 1 part of the copper solution produce a greenish liquid, which may be used at once for marking linen; but as it decomposes in a few days, it is better to preserve the two solutions separately. The writing is at first greenish, but is blackened by exposure to steam (for example, by being held over the spout of a boiling kettle). A dry heat renders the tissue brittle. (*e*) First mix 1 lb. extract of logwood with 1 gal. water; then dissolve 4 oz. sulphate of protoxide of iron in 4 oz. water; and ¼ oz. sulphide of potassium in 2 oz. water. Dissolve the logwood extract by boiling; add the potassium solution to the iron solution, until the latter assumes a black colour; then add this to the logwood solution, and boil for a few minutes. Add ½ oz. cyanide of potassium, to fix the colour; then gum and alcohol. (*f*) An excellent marking-ink is made from the resinous juice of "marking-nuts," the fruit of an

E. Indian tree (*Semecarpus Anacardium*). The "nuts" are coarsely crushed, then digested for some time in petroleum ether; the solvent is finally allowed to evaporate spontaneously. The syrupy residue when used for marking gives a brown mark, which changes to black on applying ammonia or calcic hydrate. The marks resist chloride of lime, acids, and potassium cyanide. (*g*) First, moisten the place where the letters are to be written with a solution of 1 dr. carbonate of soda and 1 dr. gum arabic in ½ oz. water, and smooth the spot with a warm iron. Next, with a quill pen, write with a solution of 1 dr. bichloride platinum in 2 oz. water. Lastly, when the writing is dry, write over the letters only with a solution of 1 dr. protochloride of tin in 2 oz. water. The marks immediately acquire a bright-purple colour. (*h*) A quicker but more expensive method is to write with a solution of chloride of gold on the linen, previously starched and pressed; on exposure to sunlight, the letters assume a bright rose-pink colour. (*i*) When a stencil-plate is used, apply with the brush a mixture of Chinese vermilion with thin copal varnish. The letters will appear red. (*j*) 22 parts carbonate of soda are dissolved in 25 parts distilled water; also 17 parts nitrate of silver in 24 parts ammonia; 20 parts gum are then macerated in 60 parts water, and mixed with the soda solution; the nitrate of silver solution is then added, together with 33 parts sulphate of copper. The ink writes a rich blue. (*k*) Dissolve 1 dr. nitrate of silver in ¾ oz. water; add to solution as much liquid ammonia as will redissolve the precipitated oxide, with some sap green to colour it, and sufficient gum water to raise the volume to 1 oz. Letters written with this ink should be first fire-heated, and then exposed to the sun to blacken. The fabric requires no previous preparation. (*l*) Write with a solution of nitrate of silver, thickened with gum, and tinted with sap green, on fabrics previously damped with solution of carbonate of soda. (*m*) Dissolve separately 1 oz. nitrate of silver, and 1½ oz. carbonate of soda; mix the solutions, and collect the precipitate on a filter; wash well; introduce the moist precipitate into a mortar, and add 8 scr. tartaric acid; triturate till effervescence ceases; add sufficient strong liquor ammonia to dissolve the tartrate of silver; add 4 fl. dr. orchil, 4 dr. powdered white sugar, and 12 dr. powdered gum arabic; make up to 6 fl. oz. with distilled water. (*n*) Crimson marking-ink may be made by adding 6 gr. carmine to the liquor ammonia of (*m*); but it soon loses its crimson tint, and becomes black. (*o*) Dissolve 25 gr. powdered gum copal in 200 gr. lavender oil, by the aid of gentle heat; then add 2½ gr. lamp-black, and ½ gr. powdered indigo. (*p*) In 18 oz. water, boil 2 oz. shellac, and 1 oz. borax; when cold, filter; add 1 oz. gum arabic, dissolved in 2 oz. water, with the requisite quantity of indigo and lamp-black. (*q*) First, dissolve together 8·5 parts chloride of copper, 10·6 parts salt, and 5·3 parts sal ammoniac, in 60 parts distilled water; then dissolve 20 parts hydrochloride of aniline in 30 parts water, to which has been added 20 parts of a gum solution (made by dissolving 1 part gum in 2 parts water), and lastly, add ten parts glycerine. These solutions are kept in separate bottles. For use, mix 1 part by bulk of the first solution with 4 parts by bulk of the second. Apply with a quill pen or small brush. The writing appears green at first, but blackens on exposure to a higher temperature.

Indian-ink.—The peculiar ink employed by draughtsmen is termed "Indian," because the best qualities have always come to us from India and China. In the latter country, the manufacture of drawing-inks is a large industry, and several factories are to be found in Shanghae and other parts of the empire.

A. The Chinese mode of manufacture is as follows:—In some parts of N. China, the lamp-black, which forms the foundation of the ink, is prepared much in the same manner as in Europe (see Blacks—Lamp-black). In other districts, the following method prevails:—The furnaces are built upon the ground, with a length varying from 8 ft. to 40 ft., or even 50 ft., and with a mouth about 2 ft. in diameter. The material generally used is pine, or other resinous wood, or the resin itself, which is burned at the mouth of the furnace. Only the black deposited at the extreme end of the furnace is used for the finest ink, all the remainder being proportionately coarser. The fineness of the grain depends also upon the slowness of the combustion. The very finest black is said to be derived from pork-fat; the next from oils and other kinds of grease. The smoothness of the ink is likewise largely dependent upon the careful sifting of the black through silken bags or sieves. The first operation in compounding the ink is to soak a quantity of the excellent glue made from buffalo-hide; when thoroughly swollen, it is set aside, and will keep in this state for several days. For use, the glue is melted in an iron pot, and as much lamp-black is added as will produce a soft paste. This paste is very carefully kneaded by hand. A small quantity of pea-oil is then added, and the whole is maintained at a temperature of 54°–60° (130°–140° F.), until the paste is found to be perfectly homogeneous. It is then poured out in the form of flat cakes, weighing 1–2 lb. each, and is left in that condition for many days, to "ripen." It often happens, when the weather is hot and damp, that the cakes become covered with mould; but this does not seem to produce any ill effect. While one set of workmen manufacture the paste, another set fashion it into the familiar forms met with in commerce. The latter sit at a bench, with a small brazier beneath; the workman warms a piece of the paste, kneads it vigorously in his hands, presses it into a mould, and places the latter under a long lever, on the end of which he sits, so as to compress the ink forcibly, for some seconds; he fills another mould in the meantime, and so the operation progresses. The moulds are made of wood, the characters to be impressed upon the cakes being engraved also on wooden dies. One of these dies is dropped into a cavity in the bottom of the mould, while another is laid on the top of the paste in the mould. Common qualities are often pressed into large moulds with several partitions, so that the cakes, when dry, can easily be broken off from each other. For wholesale manufacturing purposes, the best is simply rolled, and the sticks, perforated at one end, are strung together in bunches of ½–1 doz. The drying of the cakes occupies 5–6 days, according to the temperature. Their high polish is due to brushing over with a hard brush impregnated with tree-wax (probably that secreted by *Coccus Pe-la*, on the branches of *Fraxinus chinensis*), which has the additional effect of preventing the ink soiling the hands when they are moist. The peculiar odour possessed by the finest ink is produced by mixing a small quantity of musk, or of Borneo camphor, with the paste while hot. The common qualities are unscented. The Japanese make ink in the same way, but it is inferior to the Chinese product, as, though the glue and gelatine are equally good, less care is taken in the preparation of the lamp-black. The finest ink should be slightly brown in tint; when quite black, bluish, or grey, it is inferior. A stick of fine ink gives a clear, sharp sound, when struck; if the tone be dull, the ink is not homogeneous. The heaviest ink is the best; it improves in colour and brilliancy by age. The chief test of good ink is that it will produce a tint of any depth, without the slightest appearance of irregularity. Some cakes are worth 5–6*s*. each.

B. There are several cheaper home-made imitations of the Chinese ink, besides some recipes for improving the qualities of the latter. They are chiefly as follows:—(*a*) To improve Indian-ink for drawing, so that even the thickest lines will quickly dry, add 1 part of carbolic acid to 80 of the ink. If, by mistake, too much has been added, it may be rectified by putting in more Indian ink. If the mixture is properly performed, the ink is as easy to draw with as it is without carbolic acid, but dries quickly, and may even be varnished without discharging. (*b*) For making a deep-black Indian-ink, which will also give neutral tints in its half shades, rub thoroughly together 8 parts lamp-black, 64 parts water, and 4 parts finely pulverized indigo. Boil the mixture until most of the water has evaporated; then add 5 parts gum arabic, 2 parts glue, and 1 part extract of chicory. Boil the mixture again till it has thickened to a paste; then shape it in wooden moulds, which have been rubbed with olive or almond oil. (*c*) Most of the black Indian-ink met with in commerce possesses the disadvantage that it blots when a damp brush is passed over it; or, as draughtsmen say, "it does not stand." The addition of alum does but little good; but bichromate of potash accomplishes the object, by rendering insoluble the glue which the ink contains, and thus making the ink permanent. The bichromate of potash possesses a deep-yellow (almost red) colour, but does not at all injure the shade of the ink, as 1 per cent. of it in a very fine powder, intimately mixed with the ink, is sufficient. The bichromate must always be mixed with the ink in a dry state, otherwise the latter might lose its friability in water. A drawing which has been made with this ink in the dark, or by artificial light, must be exposed to sunlight for a few minutes, which renders the bichromated glue insoluble in water. Draughtsmen who cannot provide themselves with such ink, make use of a dilute solution of bichromate of potash in rubbing up the ink. There is no danger of the yellow penetrating the paper, if the ink is thick enough. (*d*) A substance much of the same nature and applicable to the same purpose as Indian-ink may be formed in the following manner:—Convert 3 oz. isinglass into size by dissolving it over a fire in 6 oz. soft water; dissolve 1 oz. Spanish liquorice in 2 oz. soft water, in another vessel over a fire; grind up, on a slab with a heavy muller, 1 oz. ivory-black with the liquorice mixture; add this compound to the isinglass size while hot, and stir well together, till thoroughly incorporated. Evaporate away the water, and then cast the remaining composition into a leaden mould slightly oiled, or make it up in any other convenient way. (*e*) Dissolve horn shavings with caustic alkali; boil the brown liquid in an iron kettle till it is thick; pour on double its weight of boiling water, and precipitate by dissolved alum; dry, grind, mix it with gum-water, and pour it into a mould; add perfume, if desired. (*f*) Horse-beans, perfectly calcined, are ground to a fine powder, made into a paste with solution of gum arabic, and then formed into cakes. (*g*) Mix finest lamp-black with a solution of 100 gr. lac and 20 gr. borax in 4 oz. water.

Printing-ink.—The ink used by printers is compounded mainly of two ingredients, colouring matter and varnish. The former varies according to the quality and tint of the ink; the latter may be obtained by natural resinous substances, or by mixing oil, rosin, and soap.

A. BLACK.—(*a*) The chief colouring matter in black printing-ink is vegetable lamp-black. The price of the best qualities precludes their use, except for specially fine ink; nevertheless, good ink cannot be made with inferior samples. An undue proportion of lamp-black in the ink will cause it to smear, however long it may have been printed, and to "set-off" during book-binding operations. Thus the thickest inks are not the best, if the lamp-black is more than the varnish can bind. Ivory-black is too heavy to be used alone; but a proportion ground up with the other ingredients makes a valuable ink for producing the best possible effect with wood-engravings.

Only the best and blackest is admissible. Prussian blue, ground exceedingly fine, and used sparingly, deepens the colour of ink; in excess, it gives a cold appearance. Indigo may replace Prussian blue. Perhaps the blackest tint is produced by equal quantities of each. To give a rich tone, and remove the coldness caused by indigo and Prussian blue, the addition of a little Indian red is strongly recommended.

The natural resinous substances employed as a source of varnish are balsam of copaiba and Canada balsam. The former is superior, and, when old and pure, may be used without any preparation. The latter is much thicker, and dries more quickly, and cannot therefore be used alone; but for a strong ink, a small proportion may with advantage be added either to the balsam of copaiba or to the artificial varnish now to be described.

The basis of the artificial varnish is linseed-oil, which should be as old as possible. Of all other oils, the only one recommended as a substitute is nut-oil. The rosin used may be either black or amber. It melts in the boiling oil, and combines with it, preventing its separation from the colouring matter and staining of the paper, and binding the ink to prevent its smearing. The properties possessed by soap, which render it such an indispensable ingredient of printing-ink, are that it causes the ink (1) to adhere uniformly to the face of the type, (2) to coat it completely with the smallest quantity, (3) to leave the face of the type clean, and attach itself to the surface of the damp paper by the action of pressure, and that repeatedly, (4) to wash easily off the type, and (5) to never skin over, however long it may be kept. For all dark inks, well dried yellow or turpentine soap may be employed; for light-tinted inks, curd-soap is preferable. Used in excess, soap tends (1) to render the colour unequal, where a large surface is printed, (2) to spread over the edges of the types, so as to give them a rough appearance, and (3) to prevent the ink drying quickly, and cause it to "set off" when pressed. It is thus opposed to the binding quality of the rosin. Its due proportion is when the ink works clean, without clogging.

The combination of these several ingredients is effected in the following manner:—Into an iron vessel having 2–3 times the capacity of the materials it is to receive, put 6 qt. linseed-oil, and make a fire under it. After a time, the oil simmers and bubbles up, but as the temperature increases, the surface resumes placidity; next it commences to smoke, and then to boil, emitting a very strong odour; as the boiling continues, a scum arises. At this stage, repeated tests should be made to ascertain whether the escaping vapours will ignite. At the moment when they will do so, the pot is removed from the fire, and placed on the ground, and the contents are stirred with an iron spatula, and kept burning. The pot is covered occasionally to extinguish the flame, while samples are withdrawn to test the consistence. When drops of the oil let fall upon a porcelain surface will draw out into strings about ½ in. long, the oil is suited for ink for ordinary book-work. The flame is then extinguished by firmly replacing the cover. On removing it, there is a great escape of strong-smelling smoke, and much froth; the latter is made to subside by thorough stirring, and when this is accomplished, but not before, 6 lb. of amber or black rosin is gradually introduced and stirred in. When the rosin is dissolved, 1¾ lb. of dry brown or turpentine soap, in slices, is stirred in gradually, and cautiously, as it froths copiously. When all the soap is in, and the frothing has ceased, the pot is returned to the fire till its contents boil, constant stirring being maintained. This completes the varnish. Into an earthenware pot, or a tub, of sufficient capacity, is put 5 oz. of Prussian blue, or indigo, or the two combined; then 4 lb. of the best "mineral lamp-black," and 3½ lb. of good lamp-black; next add the varnish by degrees, while warm, stirring meantime and until all the ingredients are thoroughly mixed; finally pass it through a levigating mill, or between the stone and muller, and reduce it to impalpable fineness.

(*b*) A fine, intensely black, strong ink, without the use of oil and rosin, may be made in the following manner:—9 oz. balsam of copaiba, 3 oz. lamp-black, 1¼ oz. indigo, or Prussian blue, or equal proportions of each, ¾ oz. Indian red, 3 oz. dry turpentine soap, ground between a muller and a stone to impalpable fineness. This is an excellent ink for giving good effect to highly finished wood-engravings.

B. COLOURED.—Printing-inks may be made in a number of colours besides black. The principal are the following:—

Red: (*a*) Carmine may be readily ground into a fine ink of brilliant colour by admixture with black ink varnish made with balsam of copaiba. It is expensive, but valuable for special purposes. (*b*) Crimson lake is easily reduced by the muller; it works clean, and does not require more soap than is contained in the varnish, but it does not possess much depth. (*c*) A deeper tone than can be obtained from commercial lake may be produced in the following manner:—1 oz. best cochineal, powdered, and boiled in 1 qt. water, till the colouring matter is extracted; let the cochineal subside, and pour the liquid into another vessel; when cold, gradually add some chlorate of tin, with constant stirring, till the supernatant liquid, on standing, becomes nearly colourless; then add a little powdered alum. Assist the solution by stirring; allow to subside; pour off the excess liquid; wash the coloured residue with 3 or 4 waters, to remove the acid; and dry carefully and slowly. The addition of cream of tartar during the process will give a purple tint. (*d*) Vermilion may be used for red ink where neatness is required, as for title lines of books. The quantity varies much, and necessitates care in its proportions. It requires much soap to make it work clean. (*e*) For cheap work, such as posting-bills, red-lead may be used; it requires additional soap to make it work clean, and its colour soon changes to black. (*f*) An excellent, permanent red, of rich tone, may be produced from Indian red. (*g*) Venetian red is easily ground into a smooth ink, and requires but little more soap than the varnish usually contains; it is not very intense.

Yellow: (*a*) The highest yellow is obtained from chromate of lead, which is easily ground into a fine ink, works freely and well, and requires but little soap beyond what the varnish contains. (*b*) Yellow ochre is easily ground into a fine ink; it gives a useful colour, dull but permanent.

Green: Various shades of green may be produced by suitable admixture of blues and yellows. Prussian blue and chromate of lead make a good rich green; indigo and the same yellow, a deeper, duller colour; Antwerp blue and the same yellow, a brilliant rich green. The chromate must be quite pure to ensure bright colours.

Blue: (*a*) Indigo gives a deep but dull blue; it is cold, but permanent. (*b*) Prussian blue needs much grinding, and extra soap; it affords a deep, bright colour, and is useful for making greens. (*c*) Antwerp blue is easily ground to the proper degree of fineness, makes a good ink, and works clean and well; its tint is bright and light, with a slight green tendency.

Purple: Different shades of purple may be made by grinding together carmine, or purple lake, with Prussian blue.

Engraving-inks.—Under the term "engraving-inks," will be included all inks employed for engravers' purposes, whether on stone, wood, or metal.

BLACK.—(*a*) Coal-tar, 100 parts; lamp-black, 36; Prussian blue, 10; glycerine, 10. This ink may be used for lithography, chromolithography, autography, &c. (*b*) To the varnish obtained by boiling linseed-oil, as for printing-ink, is added as much best calcined Paris black as can be ground up with it. This is a litho printing-ink. For copper-plate printing, the Paris black is replaced by lamp-black. (*c*) 8 oz. mastic in tears, 12 oz. shellac, 1 oz. Venice turpentine; melt together; add 1 lb. wax, 6 oz. tallow; when they are dissolved, add 6 oz. hard tallow soap-shavings, and mix; then add 4 oz. lamp-black. Mix all well together, let cool slightly, pour into moulds, and cut into cakes of convenient size. This ink is suited for writing on stones. (*d*) To render (*c*) liquid, for writing and drawing on transfer-paper, it is warmed in a pot, and then rubbed down with soft water (rain, or distilled water). The pen should be dipped into oil, and wiped, before use.

COLOURED.—Coloured inks are made by adding to the varnish already described, certain pigments, of which the principal are as follows:—

Red: 5 oz. mineral orange-red, 2 oz. Chinese red.

Blue: 2 oz. celestial blue, 3 oz. marine blue.

Green: 2 oz. mineral green, 3 oz. chrome-green.

Brown: 2 oz. burnt umber, 1 oz. rose-pink.

Lilac: 1 oz. Prussian blue, 2 oz. Chinese red.

Pink: 2 oz. mineral pink, 1 oz. satin-white.

Orange: 2 oz. orange-red, 1 oz. flake-white, ground up with Canada balsam, and omitting the linseed-oil varnish.

Miscellaneous Inks.—Inks for writing on metallic surfaces may be made as follows:—(*a*) 1 part verdigris (acetate of copper), 1 part sal ammoniac, ½ part soot, 10 parts water; stir well write with a quill. (*b*) 1 grm. sulphate of copper, dissolved in 20 grm. water; add 2 drops hydrochloric acid, and enough solution of gum arabic to make the ink adhesive. To make the writing appear at once, add a little pyrogallic acid. Write with a copper pen. (*c*) Dissolve 2 oz. shellac in 1 pint alcohol, filter through chalk, and mix with finest lamp-black; forms a jet-black, lustreless ink, insoluble in water. A violet ink for rubber stamps is made by mixing 2–4 dr. aniline violet in 15 oz. alcohol and 15 oz. glycerine. Gold inks are made as follows:—(*a*) 24 leaves gold, ½ oz. bronze gold, 30 drops spirit of wine, 30 grm. honey, 4 dr. gum arabic, 4 oz. rain-water; rub the gold with the honey and gum, and having mixed it with the water, add the spirit. (*b*) 1 part gold, 3 parts aqua regia; mix, and evaporate till all the chlorine is given off; cool, and mix well with ether; thicken with naphtha or essential oils. An improved method of making gold and silver inks is to triturate the purified metallic powder with a solution of 1 part white gum arabic in 4 parts distilled water, and 1 part potash water-glass.

Imports of Inks.—The value of the inks imported into the United Kingdom from all countries in 1879 was 8273*l.*

Bibliography.—W. Savage, 'Printing Ink' (London: 1832).

(See Blacks; Camphor; Coal-tar Products; Dyestuffs; Pigments; Printing and Engraving; Resinous Substances; Tannin.)

IVORY (FR., *Ivoire, Éburne*; GER., *Elfenbein*).

The term "ivory" is properly restricted to that substance which forms the main body of the long, projecting, horn-like teeth, called "tusks," of the elephant, and the other proboscidian quadrupeds belonging to the two genera, *Elephas* and *Mastodon.* It is the only form of dentine, or tooth-substance, which, in transverse sections or fractures, shows lines of different colours, or striæ, proceeding in the arc of a circle, and forming, by their decussations, minute curvilinear lozenge-shaped spaces. This peculiarity extends to the smallest fragment of true ivory, whether recent or fossil, and serves to distinguish it from all other kinds of tooth-substance, from bone, and from artificial compounds such as celluloid. The large size, and the density of the principal substance, of the teeth of many other species of animal, however, favour their application to many purposes analogous to those for which true ivory is used; these will find a place in the present article.

The economic value of teeth is dependent chiefly upon the laws of their growth. Those of limited growth, and which are incapable of renewing the waste that they suffer by wear, as in the case of man and most animals, are practically valueless; but those which continue to grow as long as the animal lives, as the tusks of the boar, hippopotamus, walrus, narwhal, elephant, and mastodon, are important objects of commerce. In teeth of unlimited growth, tooth-substance is formed at the base as fast as it is worn away from the apex, and thus the growth is uninterrupted. At first, the ratio of addition is greater than that of abrasion, and the tooth not only grows but increases in size; when the animal has attained its full size, however, the tooth is reproduced without increase of size, or augments only in length, and that solely where its surface is not abraded by an opposite tooth. The shape of the tooth or tusk, and the impressions on its surface, are due to the shape of its socket; malformations of the latter produce various abnormal forms of tusk. The tusk of the elephant is slightly movable in its socket, and may be readily made to grow in any particular direction by habitual pressure.

Having thus discussed the subject in its general bearings, it will be convenient to devote some separate consideration to each of the ivory-yielding animals—the elephant, mammoth, hippopotamus, walrus, narwhal, and dugong.

Elephant-ivory.—Existing elephants are divided into two distinct species—*Elephas indicus*, found, in several varieties, in both continental and insular Asia; and *E. africanus*, widely distributed in Africa. The most important characteristic of the Asiatic elephant, in connection with this article, is that tusks of a size to possess any commercial value are confined to the males. In the African species, the tusks of both sexes are of marketable growth, though the male is considerably the larger.

The two large permanent tusks of the elephant are preceded by two small deciduous ones, which make their appearance beyond the gum between the 5th and 7th months. They measure about 2 in. in length, and $\frac{1}{3}$ in. in diameter where they protrude; they are shed between the 1st and 2nd years. The permanent tusks cut the gum when about 1 in. long, and at 1–2 months after the "milk-tusks" are shed. At this period, the permanent tusks are black and rugged at the ends; as they grow beyond the lip, they are worn smooth by the motion and friction of the trunk. The microscopic structure of the peculiar modification of dentine called ivory is characterized partly by the minute size of the tubes, which, at their origin from the pulp-cavity, do not exceed $\frac{1}{15000}$ in. in diameter; in their close arrangement, at intervals but little greater than the breadth of a single tube; and, above all, in their strong and almost angular gyrations, which are much greater than the secondary curvatures of the tubes of ordinary dentine. By the minuteness and close arrangement of the tubes, and especially by their strongly undulating secondary curves, is produced a tougher and more elastic tissue than results from their disposition in ordinary dentine. Hence the superior value of ivory. Domestication of the elephant is usually attended by depreciation in quality, and decrease in size, of its ivory; and scientific observation has not resulted in the discovery of any means for increasing the growth, nor improving the quality, beyond the straightening process alluded to.

The tusks of the variety of Indian elephant called *Dauntelah* project nearly horizontally, and are sometimes almost straight. They are the largest of all Indian ivory, and rarely exceed 72 lb. in Bengal, and 50 lb. in Tipperah. In the *Mooknah* breed of India, the tusks are much smaller, are straight, and point directly downwards. Indian ivory has an opaque dead-white colour, and manifests a tendency to become discoloured. The exports of unmanufactured ivory from British India in recent years have been:—5936 lb. in 1874, 8288 lb. in 1875, 12,300 lb. in 1876, 10,731 lb. in 1877, 11,211 lb. in 1878. Their respective values were:—2295*l.*, 3918*l.*, 5947*l.*, 5256*l.*, 5665*l.*; and the values of the manufactured ivory exported in the same years were:—155*l.*, 212*l.*, 885*l.*, 302*l.*, 42*l.* Very large numbers of elephants are still found in Ceylon; their ivory is distinguished by fine grain, small size, and pearly bluish tint. Siam produces considerable quantities of ivory, which is considered much superior to Indian in appearance and density. The search for fossil ivory, probably of the same species as now exists, is said to be very profitable all along the W. side of the Gulf of Siam. The Singapore ivory most resembles that from Ceylon. Pegu and Cochin China afford larger tusks, up to 150 lb.

The ivory of the African elephant is much larger than that of the Indian. The animal itself is also much larger, especially to the south of 20° S. lat. Curiously enough, the nearer the equator is approached from that line, the smaller are the animals, but the larger the tusks. The latter feature may be accounted for by the greater age of the animals in less disturbed districts. The finest transparent ivory is collected principally along the W. coast of Africa, between lats. 10° N. and 10° S., and is believed to deteriorate in quality, and to be more liable to damage, with increase of latitude in either direction. The best white ivory is chiefly the produce of the E. coast of Africa generally. African ivory is considered to be in best condition when, recently cut, it has a mellow, warm, transparent tint, almost as if soaked in oil, and with little appearance of grain or fibre. In this state, it is termed "green" or "transparent." By exposure, the transparency is reduced, and the remaining delicate white line should be permanent. The quality of W. African ivory varies much. That best suited to the English market comes from the Camarone coast; Gaboon, Loando, Congo, and Ambriz rank next; these are followed by Gold Coast ivory, and that shipped at Sierra Leone and Cape Coast Castle. The Gold Coast may generally be known by having a roughly hewn hole near the end of the hollow; Gambia tusks are usually very bad, always broken, crooked, cracked in the hollows, and more or less damaged. On the E. coast of Africa, Zanzibar is the principal mart for perhaps the finest and largest ivory in the world. It collects the produce of the lands lying between the parallels of 2° N. lat., and 10° S. lat., and the area extending from the coast to Lake Tanganyika. The merchants at Zanzibar recognize three distinct qualities:—(1) The best, a white, soft and large variety, with small "bamboo," is from the Banadir, Brava, Makdishu and Marka. A somewhat inferior, harder sort is brought from the countries of Chaga, Umasac and Nguru. The Wamasai often spoil their tusks by cutting them, for facility of transport; and, like the people of Nguru, and other tribes, they stain the exterior with smoke, as a supposed preventive against their cracking or splitting in the sun. (2) The second quality is imported from the regions about Lake Nyassa, and carried to Kilwa by the Wabisa, Wahido, Wangindo, Wamakua, and other clans. The "Bisha" ivory formerly found its way to Mozambique. (3) The third and least valued quality is the western variety, the gendai, and others imported from Usagara, Ujiji, Urori, Unyamwezi, and its neighbourhood—Mgunda Mkhali, Usukuona, Umanda, Usagozi, &c. The ivory of Ujiji is collected from the provinces lying around the northern end of the lake, especially from Urundi and Uvira; these tusks have one great defect: though white and smooth, when freshly taken from the animal, they put forth, after a time, a sepia-coloured or dark-brown spot, extending like a ring over the surface, and gradually injuring the texture. It is apt to flake off outside, and is little prized on account of its lightness. Burton instances a lot of 47 tusks at Zanzibar averaging 95 lb. each, 80 lb. being considered moderate, and 70–75 lb. poor. Specimens weighing 175 lb. are not uncommon, and even 227–280 lb. is spoken of. At a London sale, Zanzibar tusks averaged 122 lb., Lagos 114 lb., Cape and Natal 106 lb., Gaboon 91 lb., and Angola 69 lb.; but these figures are not an absolute guide. Large quantities of ivory find an outlet at the Cape and Natal. The former exported 143,682 lb., value 60,402*l.*, in 1875; 161,234 lb., 58,626*l.*, in 1876; 137,660 lb., 50,711*l.*, in 1877; and 149,701 lb., 50,155*l.*, in 1878. The latter shipped 27,792 lb., 9430*l.*, in 1875; 29,172 lb., 11,048*l.*, in 1876; 43,119 lb., 15,014*l.*, in 1877; 37,136 lb., 12,054*l.*, in 1878. Of late years, a considerable quantity of ivory is brought by caravan across the desert to the various ports of N. Africa. Thus, the value of the export from Tripoli was 30,800*l.* in 1878, and 21,000*l.* in 1879; that from Bengazi, in 1878, was 5000*l.* (all to England); while those from all Egyptian ports, in 1879, were: to Great Britain, 4400*l.*; France, 1500*l.*; Italy, 1330*l.*; Austria, 530*l.*; Turkey, 260*l.*

Fine ivory is known by having no cracks nor flaws, whether in the solid or in the hollow; their presence is a serious detriment. Tusks that taper very gradually are preferred, and those which have a small hollow, i. e. are as straight as possible. Sharply-tapering and much-bent tusks cause great waste in cutting up. Tusks damaged at the point are inferior, and depreciated internally. The coat should be fine, thin, clear, and transparent. The applications of ivory include almost all ornamental articles of turnery, as well as knife-handles, brush-backs, combs, piano-keys, &c. "Scrivelloes," or tusks weighing less than 20 lb., are principally converted into billiard-balls. The ivory for piano-keys, combs, and other square articles, is cut into shape by means of very fine circular saws. The goods are polished and bleached. The latter operation is performed either by exposure to sunlight for periods varying from 4 weeks to 6 months, or by immersion in turpentine (kept near the surface), accompanied by exposure to sunlight for 3–4 days. When bleached, the ivory may be dyed. For ordinary dyestuffs, it will need to be first mordanted by soaking for 6–8 hours in vinegar, or alum solution. Red may be produced by a decoction of peach-wood; yellow, by saffron; green, by a solution of 3 parts verdigris and 1 part ammonia in vinegar; blue, by following the green bath with potash lye; black, by logwood decoction and acetate of iron. Coal-tar colours may also be used. Ivory is silvered usually by immersion for a few minutes in a nitrate of silver bath, and then in clean water exposed to the sun; or by exposure to the fumes of phosphoretted hydrogen after the silver bath. It may be made flexible by immersion in pure phosphoric acid, of sp. gr. 1·13; it hardens again on exposure to the air, but resumes pliancy when put into hot water.

Mammoth- or Fossil Ivory.—The tusks of the extinct *Elephas primigenius*, or mammoth, have a bolder and more extensive curvature than those of *E. indicus.* The numerous specimens which have been discovered may be ranged under two averages of size—the larger at 9½ ft. long, the smaller at 5½ ft. Prof. Owen assigns the smaller to the female animal, and thus makes the mammoth more nearly allied to the African than the Indian elephant of the present. This extinct elephant roamed in countless herds over the temperate and northern parts of Europe, Asia, and America, and its remains are now found in great abundance in Siberia and Alaska, preserved in the frozen soil. The erosion of the soil along the banks of the great rivers feeding the Arctic Ocean discloses every year very large quantities of this fossil ivory, the chief centres for its barter being Yakutsk, on the Lena, Turuchansk, on the Jenesei, and Obidorsk, on the Obi. Numbers of tusks are also found scattered about on the Tundras; while the richest harvest of all is gathered from the New Siberia Islands. Probably the total annual production of fossil ivory in Asiatic Russia amounts to 20,000–30,000 lb., the average weight of a pair of tusks being placed at 200 lb. The largest rarely leave the country, being either too rotten for industrial purposes, or so heavy that the natives are obliged to saw them up for removal. This latter fact causes great waste of the material. The tusks were an article of export to China at least 7 centuries ago, and no signs are yet visible of any diminution in the supply. Some were sold in London in 1876 at prices varying from 22*l.* to 43*l.* a cwt. Recent explorations on the Yukon river, in Alaska, are said to indicate the existence of even larger quantities of fossil ivory than have been yielded in Siberia.

Hippopotamus-ivory.—The hippopotamus, or "sea-cow" (*Hippopotamus amphibius*), is a native of Africa, in some parts of which, it is found in great abundance. The teeth of this animal which possess commercial value are of two kinds—the "canines," and the "incisors." The former are 4 in number, 2 in each jaw; those of the lower jaw are the larger; both are much curved. They are composed principally of an extremely dense, compact kind of dentine, protected on the most exposed portions of the surface by a thick layer of enamel, so hard as to strike fire with steel. The incisors number 8, are various in size, but all smaller than the canines, and are of less value. Usually only the two lower, lateral, projecting incisors are imported. The larger proportion of mineral matter in the dentine of the canines, as compared with elephant- or walrus-ivory, and its great density of formation, render it harder, and less liable to receive stains, than other similar substances, whilst the smaller amount of organic matter, and the almost complete absence of oily particles, account for its superior and delicate whiteness. These latter qualities, on the other hand, induce a certain brittleness, and render it easily acted upon by organic acids. The enamel is still whiter and harder than the dentine. Formerly, the canines were largely used by dentists, for making artificial teeth; but they have latterly been replaced by substitutes less liable to destruction by the acids met with in the act of eating. They are much employed in France, for the production of delicate intaglios; they are also superior to ivory for handles of surgical instruments, &c. For all but dental purposes, the enamel is first removed by an acid bath. The incisors are too soft to be of any value to dentists; the two long lower ones are made into knitting- and netting-needles, and similar articles. The smaller and curved upper incisors are fit only for common turnery. At one time, we imported 7–10 tons annually, worth up to 30*s.* a lb; the quantity now is small, and the value only 1*s.* 6*d.*–2*s.* 6*d.* a lb.

Walrus-ivory.—The walrus, or "sea-horse" (*Trichecus Rosmarus* [*Rosmarus obesus*]) is a native of the Arctic regions, being found abundantly on the coasts and islands of Alaska, where some 50,000 are obtained every year by the American whalers. The tusks of the animal are limited to a single pair, growing from the upper jaw, and descending outside the lower jaw. Their substance is less dense and coarser than the dentine of the hippopotamus tusk, and is of proportionately less value in commerce. They weigh about 4 lb. a pair, and sometimes attain a length of 2 ft. They were formerly in demand for dental purposes, and are much used in Chinese turnery. The quantity annually produced in Alaska amounts to about 100,000 lb.; and the Hudson's Bay Co. sometimes import 100–200 lb. in a year.

Narwhal-ivory.—The narwhal or "sea-unicorn" (*Monodon monoceros*) is also an inhabitant of the Arctic seas. The tusks are reduced to a single tooth, restricted to the male. It grows from the upper jaw, in a straight line; its exterior is marked by spiral ridges, which wind from within, forwards, upwards, and to the left. About 14 in. is implanted in the socket, and this is the most solid and weighty portion; it tapers gradually from base to apex, and attains a length of 9–10 ft., and a diameter of 4 in. at the base. It is, in fact, the left tusk of a pair, the right one being abortive, but always to be found in a rudimentary state, and occasionally protruding for a few inches. Denmark has sometimes imported 100 tons of these tusks (miscalled "sword-fish horns") from the Arctic seas in one year. The Greenland Co. collected 457 lb., valued at 175*l.*, in the year ending March 1875. The substance of the tusk is comparatively coarse, and of little value.

Dugong-ivory.—The Australian "dugong" (*Halicore australis*) is best known as affording a valuable animal oil, and is therefore described at length under Oils; but it also yields a kind of ivory. According to some accounts, the intermaxillary bones of the animal possess a fineness and hardness of grain, specific gravity, and appearance closely resembling ivory, and may be generally used as a substitute for elephant-ivory. Other accounts speak only of the two large incisor teeth or tusks, which adorn the head of the male, as being suitable for such purposes. Some cwt. have formerly been shipped from Moreton Bay, and valued at 60*s.* a cwt.

Imports and Values of Ivory.—Our imports of ivory—designated, in the Custom-House Returns, as elephants', sea-cows' and sea-horses' "teeth" (the commercial term being, in this case, scientifically correct)—in 1879 were as follows:—From Holland, 580 cwt., 23,876*l.*; Malta, 648 cwt., 26,203*l.*; Egypt, 685 cwt., 37,530*l.*; Aden, 440 cwt., 21,505*l.*; E. coast Africa, native states, 650 cwt., 32,511*l.*; British S. Africa, 1367 cwt., 62,772*l.*; British W. Africa, 85 cwt., 3337*l.*; W. coast Africa, Portuguese possessions, 275 cwt., 11,613*l.*; W. coast Africa, not particularly designated, 1801 cwt., 69,798*l.*; Bombay and Scinde, 1737 cwt., 79,065*l.*; Bengal and Burmah, 55 cwt., 2625*l.*; other countries, 1091 cwt., 36,092*l.*; total, 9414 cwt., 406,927*l.*

The approximate relative values are:—Elephant-ivory: 70 lb. each, and upwards, 50–70*l.* a cwt.; 50–70 lb., or "seconds," 45–65*l.*; 35–50 lb., or "thirds," 40–60*l.*; 20–35 lb., or "fourths," 30–50*l.*; "scrivelloes," 12–34*l.*; solid scrivelloes for billiard-balls, 45–65*l.*; cut pieces for billiard-balls, 50–75*l.* Sea-horse (walrus) teeth, 6*d.*–8*s.* a lb.

The chief substitutes for ivory are an artificial compound termed "celluloid," and the hard vegetable kernels called "corozo-nuts."

Bibliography.—R. Owen, 'Ivory and Teeth of Commerce' (Jour. Soc. Arts, Vol. v., No. 213, London: 1856); P. L. Simmonds, 'Animal Products' (London: 1877).

(See Bones; Celluloid; Horn; Nuts—Corozo-nuts).

JUTE MANUFACTURES.

The use of jute as a textile fibre, though known ages since in India, is only of recent introduction into this country. After the manufactures of India had been made familiar to the English public, attention was turned to the raw products of the country, amongst which the numerous indigenous fibrous plants engaged a great share. The use of jute for the manufacture of gunny-bags, canvas, carpets, and various other purposes, by the Hindoos, suggested its adaptability for similar textures at home. Towards the close of the last century, small lots of the fibre were imported into this country, and also to Hamburg and America, with the view of introducing it to manufacturers. But it was not favourably regarded, and, though for several years afterwards the E. India Co. repeated the experiment, the fibre continued in neglect, and remained comparatively unknown. Abingdon, in Oxfordshire, noted for its manufactures of woollen carpets, canvas, tunics, and similar fabrics, received some of these first importations; and here the first serious attempts were made to test its utility. Some of the fibre having been spun by hand, the yarn produced was discovered to possess some resemblance to woollen yarn, which led to its being dyed, and manufactured into carpets. This was probably between the years 1 20–5. Tentative efforts continued to be made throughout the following 10–15 years. These took place chiefly at Dundee, at that time one of the principal seats of the linen manufacture. The fibre was tried in hand spinning, shed-spinning, and upon power flax machinery, which last was then beginning to be introduced into the trade. There was, however, much prejudice against it, and great reluctance to devote either money or effort to the experiments. The unsatisfactory results of previous trials of unknown Indian fibres engendered considerable distrust concerning all similar articles from that country. But it was not manufacturers alone who looked askance at the fibre: merchants, dealing in the classes of goods into which it was proposed to introduce it, refused to have anything to do with it, and required guarantees that the fabrics they purchased should contain none of it. Yet notwithstanding these obstacles, experiments were repeated in various directions, though on the smallest scale; and here and there, such results were obtained as encouraged persistence in the efforts to obtain something useful from it. From 1832, may be dated the practical success of these endeavours. At that time, Mr. Watt, a linen merchant, more far-seeing than most of his competitors, perceived its adaptability for several of the fabrics manufactured in the locality, particularly cotton-bagging, then rising into great demand. The length of the fibre, however, as compared with others in use, was a great drawback. Watt therefore got an old breaker card erected, and passing the jute through this, reduced it to a manageable length. The results of attempts to spin it in this form must have been more satisfactory, as Watt's difficulties diminished rapidly, several of the leading spinners becoming free purchasers of the raw material. From that time, its progress has been one of steady growth in public favour, until it has attained the important position it now holds amongst the textile industries of this country.

The jute consumed in our manufactures is chiefly imported from Bengal, where it is largely grown. After being assorted into different qualities, it is packed in bales containing about 400 lb.

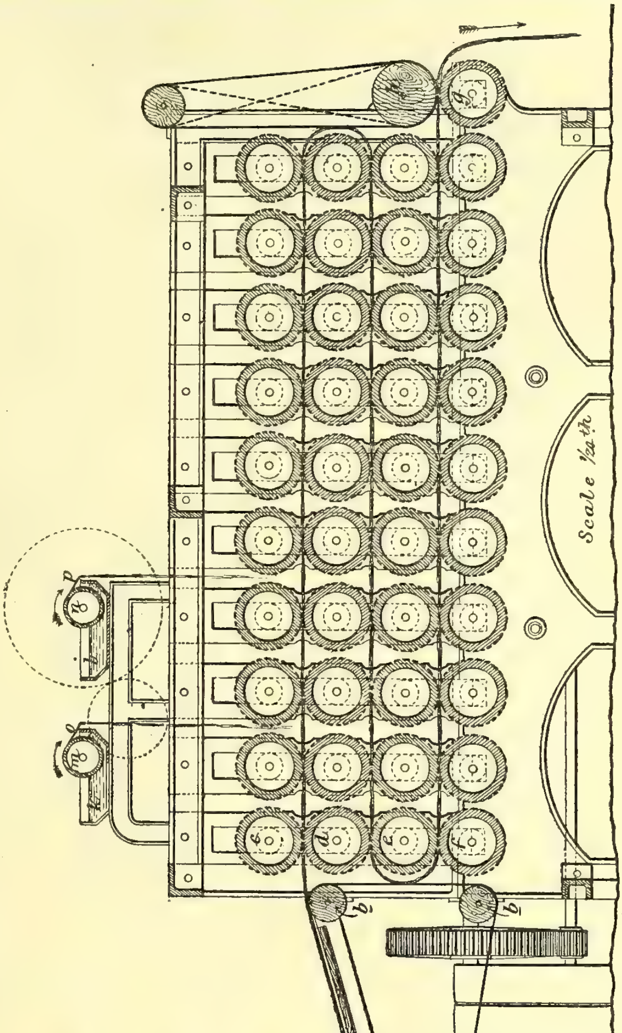
each, and exported to the principal centres of consumption, the seaports nearest thereto, and often to other places, such as London and Liverpool, being a convenient return cargo.

The processes of manufacture which jute undergoes in the first division, are :—Softening, carding, drawing, roving, and spinning. These leave it in the form of yarn.

Softening.—Owing to the harsh character of the fibre, which renders it ill adapted for spinning, and which was one of the greatest difficulties encountered in the first experiments with it, the raw material requires to be subjected to the process of "softening." After being taken from the bale, the fibre is passed between a series of heavy fluted rollers, which crush and crimp it so that it becomes much more amenable to torsion than before.

Fig. 861 exhibits a longitudinal section of the softening-machine, by means of which this is accomplished. It consists of four rows of rollers, 10 in each row, which are superimposed on each other. These rollers are 9 in. in diameter, and 2 ft. 6 in. in length. They are deeply fluted, as may be seen in Fig. 862, which is upon a scale of $\frac{1}{8}$th the size of the object; they are held in position by their axles being inserted in vertical slots in the side of the frame. The top roller rests upon the second, these two upon the third, and the whole three upon the bottom one. A feed-apron *a* is attached to the front of the machine. Over the top, are placed two cisterns *k l*, the first of which is a reservoir of water, and the second of oil. Each of these contains a revolving roller *m n*, which dips half its circumference into the fluids. Impinging against the upper surface, is a "doctor" or scraper *o p*, extending across the length of the roller, and the outer edge of which passes beyond the cistern. This is arranged to form an inclined plane, the lower edge being that away from the roller. At the extremity of the machine, are a pair of delivery-rollers, the bottom one of which is fluted, the superincumbent one being plain.

861.



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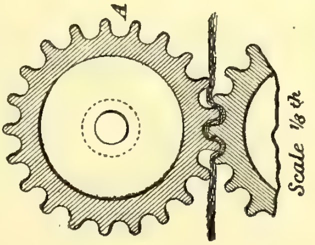
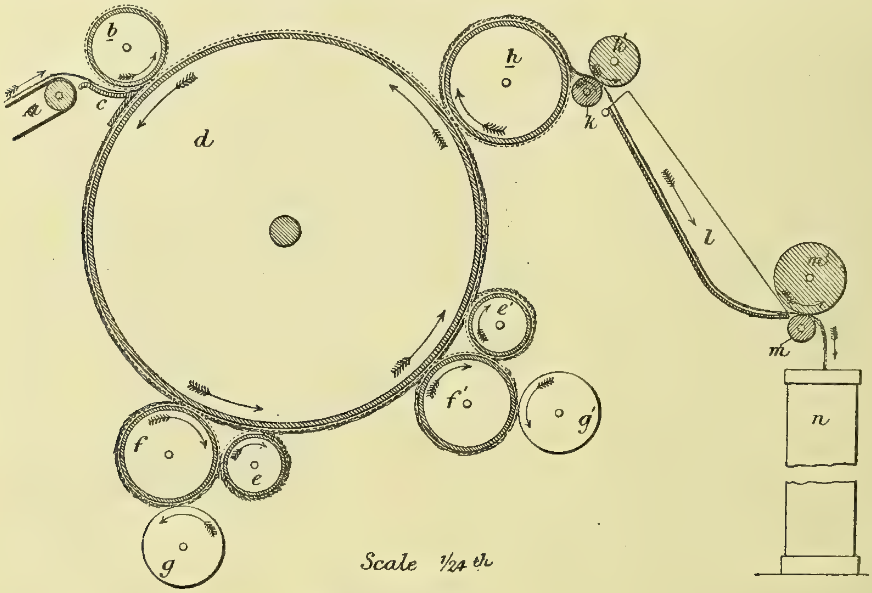


The process is as follows :—The "stricks," or handfuls of jute, are evenly fed upon the travelling apron *a*, which is actuated by the three rollers *b*, and travels in the direction of the arrow, the layer of fibre passing between the rollers *c d*, thence along the series, around the last of which it descends to retrace its course to the front of the machine, coming out between the rollers *d e*, down the front of which it again descends, and passes between the third and the bottom series, emerging from between the delivery-rollers *g h*. It will be observed that, when the fibre passes between the rollers *a b*, it is subjected only to the weight of the upper row of rollers; on its return, this weight is doubled, as the fibre is then passing under the two upper rows, after doubling from which, it is subjected to the weight of the three uppermost rows of rollers. The action of the corrugated surfaces of the rollers is also assisted by a slight lateral traverse, which is imparted to them to increase their effect.

Formerly jute was subjected to a process called "batching," in which the fibre was spread in layers, and sprinkled with oil and water, afterwards being left for several days, so that the mass might become uniformly permeated by the moisture, and thereby softened for the card. This is now more efficiently performed by means of this machine, with its attachment, as mentioned above, consisting of the water-cistern *k*, and the oil-cistern *l*, which, by means of the revolution of their respective rollers, discharge their contents upon the jute, as it is passing between the first rows of rollers. The even distribution of the oil and water, which is thus secured, and to which is added the further distributive effect of the lateral motion of the rollers, so uniformly moistens the mass of the fibre, that the necessity of allowing it to lie in heaps for several days is obviated. The softening process having been completed, the fibre is weighed into bundles, and conveyed to the card.

Carding.—In the first or breaker card, the length of the fibre, naturally 6–7 feet, is broken down to 14–18 in., which length it retains until it reaches the spinning process. The essential parts of the breaker card are shown in section in Fig. 863, and consist of a revolving feed-lattice or apron *a*;

863.

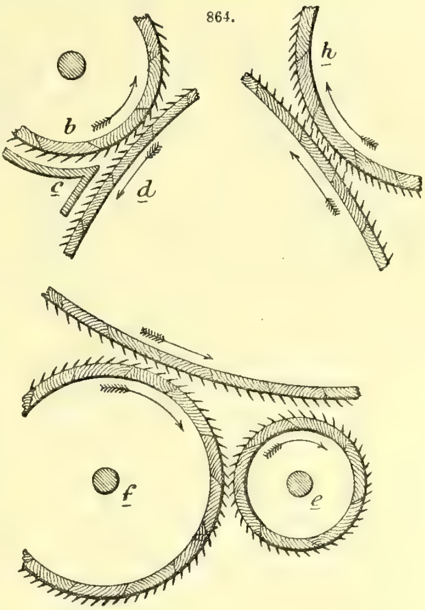


a feed-roller *b*, which possesses a concentric plate or shell *c*, placed on its lower side; the main carding-cylinder *d*, of about 4 ft. diameter and 6 ft. wide on the working surface, which is covered with strong steel cards or pins, arranged so as to incline slightly in the direction in which the cylinder revolves (Fig. 864); two pairs of workers and stripper-rollers *e f*, each pair having a tin roller *g*, for pressing the fibre into the card of the stripper to prevent its falling, and ensure its being carried around its periphery until delivered to the main cylinder again; a doffer-cylinder *h*; doffing-rollers *k*; conductor *l*; delivery-rollers *m*; and sliver-can *n*.

In the operation of this card, the stricks of jute are evenly laid by the attendant upon the endless feed-apron *a*, with their foot- or root-end foremost, all joints being carefully broken. The movement of the apron conveys it to the feeder *b*, whose surface speed being only about 10 ft. a minute, the fibre is drawn slowly forward, and pressed into the teeth of the roller by the concentric plate *c*. As the feed-roller revolves, the fibre is presented to the action of the main carding-cylinder *d*, the surface revolution of which, being at the rate of 2000 ft. a minute, strikes the fibre with great force in a downward direction, thereby combing and dividing it very efficiently before the feeder and the concentric plate relinquish their hold. It is also obvious that a large quantity of the fibre will be broken or torn away by the great rapidity and severe action of the main cylinder. These portions, being carried on the card-points of the cylinder, are caught by the workers and strippers, and are opened and combed by their action.

The fibre is carried by the main cylinder down to the first worker *e*, which is the foremost to act after the cylinder has taken the jute from the feed-roller. The worker is about 9 in. in diameter, and has a surface speed of 50 ft. a minute. Its carding-pins or points are inclined at a more acute angle than those of the main cylinder, and in a direction opposite to that of its revolution, which is the same as the contiguous surface of the main cylinder (Fig. 864). As a consequence, the fibres, being partially thrown off the surface of the main cylinder by centrifugal force, are caught upon the pins of the more slowly-revolving worker, the points of which are inclined for their reception, the worker *e* being adjusted so that its pin-points shall be $\frac{1}{16}$–$\frac{1}{8}$ in. from those of the cylinder. The action of the main cylinder is therefore to pull the fibres upon the pins of the worker, and to carry them well towards their base, by which means, the latter roller succeeds in retaining a great portion of that which has not been sufficiently opened in the first stage of its passage through the machine. The worker, having thus secured possession of, and assisted to comb out more perfectly, the unopened fibre, is cleared in turn by the stripper *f*, a roller about 13 in. in diameter, and having its card-points inclined in the direction of its revolution (Fig. 864), and a surface speed of 450 ft. a minute, by which means, it is enabled to strip the worker *e*, whose cards are inclined to deliver them to its action. The latter in turn is similarly inclined to, and is stripped by, the main cylinder, revolving at a much quicker rate. The second worker and stripper perform a similar function, but they are adjusted a little closer than the above to the main cylinder, so that they will operate on any portion of the fibre that may have escaped the action of the preceding parts.

864.



All the jute having been thus delivered again to the main cylinder, and, in its progress to this point, having been combed and carded until it is clean, and its fibres are laid parallel, it is carried along by the revolution of the cylinder, until the doffer *h* is reached. This is a roller of about 16 in. in diameter, covered with rather finer cards than the preceding, and which are inclined away from the direction of its revolution. It is set still nearer than any of the preceding, its points almost touching those of the cylinder. This arrangement, combined with its relatively slow pace, enables it to strip all the carded fibres from the cylinder, whence it is carried to the small pair of doffing-rollers *k*, which receive it in a thin sheet or fleece, and pass it into the conductor *l*, which, from being the width of the rollers at the top, narrows until it is not more than 4 in. across. The fleece, in its transit along this way, is condensed into a sliver, and passes through the delivery-rollers *m*, falling into the sliver-can *n*, when the work of the breaker-card is completed.

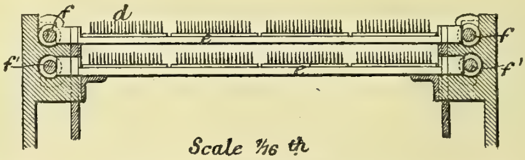
The surface speeds of the doffing-rollers *k* and delivery-rollers *m* are usually about 14 times the rate of the feed-roller *b*, hence, when the lap of jute is fed to the machine at about 2 lb. to 1 yd., it will be delivered at the opposite side in the sliver, attenuated 14 times = 7 yd. to 1 lb.

Jute being, like flax, capable of minute subdivision in its fibres, is usually submitted a second time to the process of carding. The machine used in this case is called the finisher-card, and, in its essentials, is exactly similar to the breaker-card. The differences consist in the cards upon all the rollers being finer than in the preceding case, and in each roller being set closer to its work. According to the comparatively rough or fine quality of work required, the pairs of working- and stripping-rollers are less or more in number, varying from three to five pairs, the latter being employed when the best work is wanted.

Twelve cans containing the carded jute from the breaker-card are placed behind the finisher, and the sliver from each, laid upon the endless apron, forms a lap, which passes into the machine, and is further combed and subdivided to the required state. The irregularities which will obviously occur in the sliver from the breaker-card, are, by this means, almost eliminated; and, as the speeds of the feed-roller and doffing-rollers are, in this case, 16 to 1, further attenuation takes place, the sliver delivered being of about 9½ yd. a lb., and, as compared with that from the breaker, much more level.

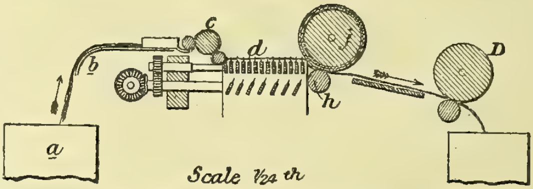
Drawing.—The sliver from the finisher-card is next required to undergo further attenuation, and to have its fibres placed in more perfectly parallel order. This is accomplished by the spiral gill drawing-frame, whose essential parts are shown in Figs. 865, 866, 867, 868. There are other kinds of these frames, but that illustrated is in most general use. Fig. 865 is a transverse section, showing the traveller-bars with the gills mounted upon them. Fig. 866 is a longitudinal section while the process is in operation. Fig. 867 gives an enlarged representation of the travelling-bars and the gills or hackles, which are seen in section in the preceding Fig., 866. In Fig. 868, is illustrated an enlarged section of the travelling-bar carriage.

865.

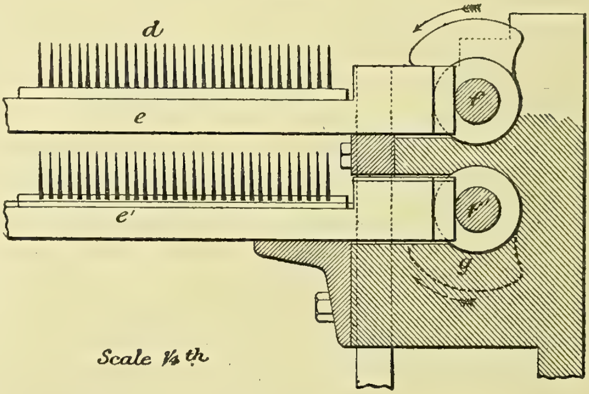


In operation, the cans *a*, containing the slivers from the finisher-card, are placed behind the machine. The slivers are then passed over the guide-plate *b*, and conducted to the retaining-rollers *c*, passing under the first, over the second, and under the third. These constitute the feed-rollers, their function being to supply the fibre to the gills *d*, upon the travelling-bars *e*, best seen in Figs. 867, 868. These bars are arranged just in front of the delivery side of the rollers, and each bar carries four "gills" or "hackles"—brass stocks filled with a row of vertical steel pins. On each side of the bars, are two shafts extending longitudinally across the machine, and one placed above the other. These have a large thread turned upon them in the middle portion of their length (*f*, Fig. 868), and are called the top and bottom screws. The top screws are cut at a pitch varying from 1½ to 2 threads an inch. The ends of the travelling or gill-bars are bevilled, so as to fit into the angle formed by the thread of the screws, the body of the bars and the gills they are carrying being thus maintained in a vertical position. In working, by the revolution of the shafts, the bars are made to travel forward from the retaining-rollers, carrying with them the gills, whose pins, having penetrated the sliver, draw the jute along with them, their speed slightly exceeding that of the rollers delivering the sliver, which secures the latter being held tightly, so that it is prevented rising from the pins. The bars move upon steel slides, which keep them at an uniform elevation, and secure them in their proper position. The threaded part of the shafts is proportioned to the length of the fibre, being 10–11 in. for carded jute.

866.



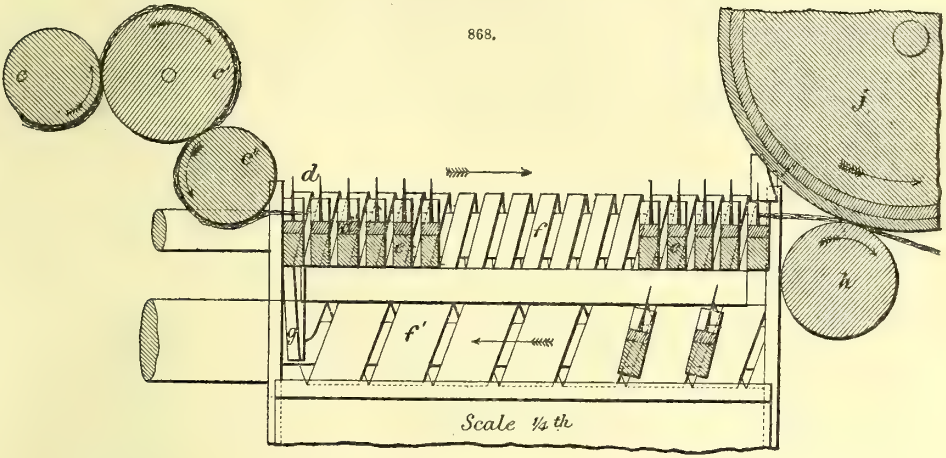
867.



On the arrival of each bar at the end of the top screw *f*, it drops from its position, the slides being purposely cut short to allow of this, upon the two bottom screws *f'*, into the threads of which, its bevilled extremities enter, as in the top screws. These screws are adjusted accurately, so as to receive the bars correctly. They are cut to the same hand as the top ones, but with a much quicker thread. They revolve in a direction opposite to those of the top, by which action, they carry back the bar to the position whence it started at the opposite end of the frame. The thread of the bottom shafts terminates in a projecting cam *g*, by which the bar is lifted again into the top shafts, the gill-pins in its elevation penetrating the sliver in process of delivery by the retaining rollers: thus commencing its journey anew.

At the front of the machine, where the sliver is delivered by the gills, are two rollers, the lower one *h* being composed of steel, about 2½ in. in diameter, and called the drawing-roller. The superincumbent one *j* is of cast iron, covered with leather, about 8 in. in diameter, and is called the pressing-roller. These rollers are pressed together by weighted levers, and revolve at a speed 6 or 7 times greater than that of the retaining-rollers *c*, or the movement of the travelling bars. The effect of this is that the sliver is seized by these rollers as the travelling bars drop from the top to the bottom screws, and drawn away from the pins of the gills, and that it is greatly attenuated, the gills which have not fallen retaining a sufficient hold of the sliver, and acting as a comb, holding the fibres back, and preventing them entering the rollers in a tangled state. After passing these, the sliver goes over a guide-plate between the delivery-rollers, and is again received into a can.

868.



The above parts constitute one division of a drawing-frame. The travelling bar is 3 ft. long, and fixed upon it are 4 gills, which are 6 in. wide at the pins. Each set of bars and gills, with their complement of retaining-, drawing-, and delivery-rollers, form a carriage; and frames are usually composed of two, three, or four of these carriages. In a drawing-frame of two carriages, containing four gills per carriage, there are eight sets of gills. Two slivers from the finisher-card are put up to each gill, the number of slivers required to supply such a frame therefore being 16. The card-sliver being about 9½ yd. to the lb., and the draught of the rollers as 6 to 1, with two slivers for each gill, the drawing-sliver as delivered from the rollers will be about 28½ yd. to the lb. But as there are still inequalities in the sliver, it is usual to double them after leaving the gills, by passing two of them together over one guide-plate, and through the above-mentioned delivery-rollers into one sliver-can, as, in that form, they are more convenient for the second drawing, to which they are next conveyed. The sliver, having thus been doubled, is, at this stage, about 14 yd. to the lb.

The second drawing-frame is of similar construction to the first, the only differences being that the gill-pins are finer and more closely set, and that the slivers are delivered singly from the drawing- to the delivery-rollers, and thence to the cans. Two slivers having again been put up to each gill, and the draught being 6 to 1, the strand is here attenuated to a length of 42 yd. to the lb.

As in the case of almost every other textile fibre, the object of these preparatory processes is to clean, comb, and attenuate the fibres, so as to fit them for the last operation of spinning into a thread, of dimensions suitable for the purpose to which it is intended to be applied. The roving-frame is the next to receive the sliver, and its function is to further attenuate it, and deliver it in a form convenient for the next stage of treatment.

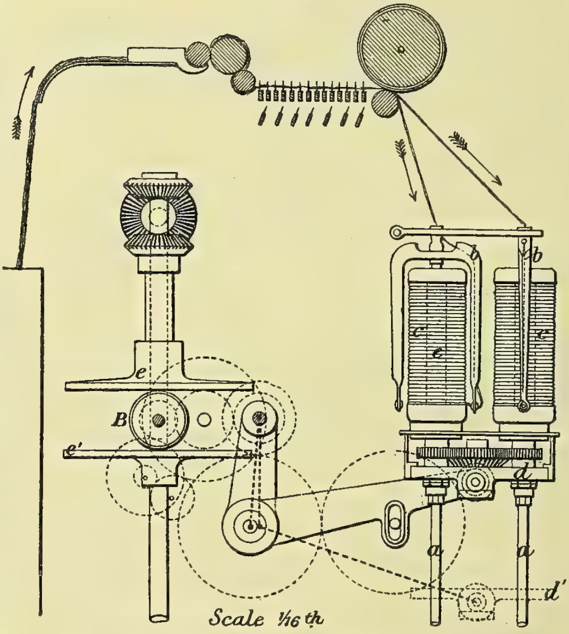
Roving.—In its chief parts, the roving-frame resembles the drawing-frame, the sliver-cans delivering their contents over a guide-plate to a set of three retaining-rollers, thence to the gills on the travelling bars, which carry it to the drawing-roller, between which and the presser, it passes to a flier-spindle, carrying a large bobbin, upon which the rove is wound, instead of, as in the preceding operations, being deposited in a can. Owing to the attenuation which the sliver has undergone, all the preceding parts of the machine are reduced in dimensions. One sliver only being put up to each gill, in this instance, the latter are made much smaller, the gill-pins being finer and more closely set than in the preceding machines, which enables eight gills to be mounted on one travelling bar, in place of four, as previously. The draught in this case is usually as 7 to 1, so that the roving is greatly reduced in dimensions, measuring about 294 yd. to the lb. This necessitates the introduction of the flier-spindle, and the use of the bobbin as a receptacle for the roving.

The spindle and flier of the jute roving-frame are, with the exception of their dimensions, exactly the same as those employed in the cotton trade. Here, however, the parts are larger and stronger, as befits the heavier fibre to be treated. The number of spindles in a frame may be either few or many, ranging between 24 and 64 to each frame. A common size contains 56 spindles; and as there is required a gill to each spindle, and eight gills form the complement of each carriage, there are consequently 7 carriages in a frame of 56 spindles.

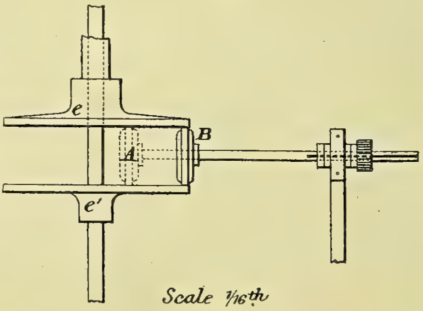
The spindles *a*, with their fliers *b* on the summit, are arranged in two rows in a vertical position in front of the frame, as shown in section in Fig. 869. The spindles are actuated by gearing at the foot, and make about 600 rev. a minute. The arms of the flier are tubular, the rove, after leaving the drawing-rollers, being conducted downwards through them to the extremity of the arm, whence, passing through an eye or curl, it is wound upon the bobbin.

The bobbin is driven by gearing similar to that which turns the spindles, but of which it is quite independent. The course of its revolution is in the same direction as the flier, and either flier or bobbin may be arranged to lead. As a rule, it is the former that takes precedence, with the bobbin following. The twist imparted to the rove should not be more than is necessary to secure its coherence when being drawn from the bobbin in the subsequent process. Assuming a case in which the frame is arranged for the flier to lead, and supposing that one turn a minute is sufficient for the roving being produced, with the spindles making 600 rev. a minute, the following conditions require to be observed. The drawing-roller must be arranged to deliver 1 in. for each rev. of the flier, and the speed of the bobbin must be retarded, as compared with the spindle, to a degree sufficient to enable it to wind up the quantity of roving delivered by the drawing-rollers. In this case, the roller delivers 600 in. a minute, the spindle and flier make 600 rev. a minute, and the shank of the bobbin *c*, which is shown by the dotted vertical lines, is 5 in. in circumference. Dividing the number of in. (600) delivered by the roller by the winding surface (5 in.) = 120, then 600 − 120 = 480, is the speed at which the bobbin is required to run to wind up the 600 in. But this is not a constant rate: every layer of roving wound upon the bobbin enlarges the circumference of the winding surface. If the bobbin were to remain constant, the roving would be rapidly attenuated, or so over-run as to be broken in every case long before the bobbin could be filled. These results are obviated by means of differential driving-gear, the essential parts of which are seen in Figs. 869, 870. The roving is first wound upon the bare shank of the bobbin in an even layer, and each succeeding one upon that which has gone before, until the bobbin is filled. This is accomplished by mounting the bobbins on a lifting-rail *d*, whose traverse extends downwards to *d'*, by which means, the bobbins *c* are moved upwards and downwards through the same space, and the rove is placed in even layers by the flier. The deposit of each layer of rove upon the bobbin increases the circumference of the winding surface of the bobbin, but the drag which this would cause is prevented, by the speed of the bobbin being accelerated in exact proportion to its increased winding surface, so that it still continues to take up only the 1 in. delivered for each rev. of the flier. This acceleration of the speed is caused by a projection attached to the lifting-rail, which is so arranged as to release a catch each time the rail arrives at the top and bottom of its traverse. The regulating motion is obtained from a bowl or pulley B, Figs. 869, 870, having a leather face, which is made to revolve by frictional contact between two flat, circular, iron discs *e*, rotating in opposite directions.

869.



870.

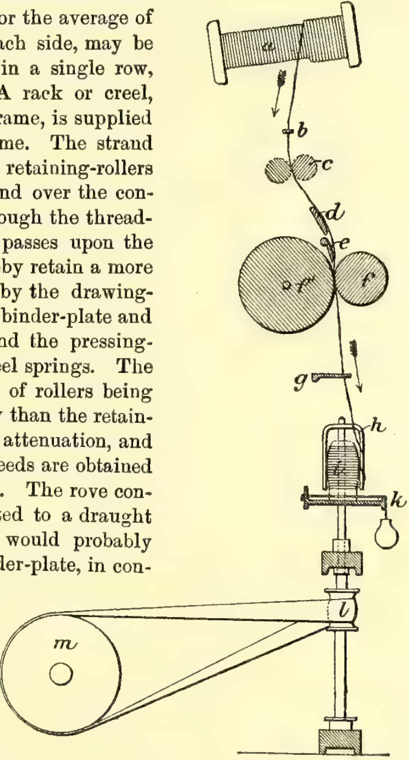


In commencing to fill a set of bobbins, the friction-bowl B occupies the position shown by the dotted lines at A (Fig. 870), which is its starting-point. Each time that a catch is released, either at top or bottom of the traverse, the bowl, with the shaft on which it is fixed, is allowed to slide outwards a little from the centre of the two discs *e*, whereby its speed is increased, and that of the bobbin correspondingly accelerated, for each additional layer of rove that the bobbin receives; and when the bowl has arrived at the position B (Fig. 870), the bobbin has attained its maximum speed, is filled, and is then ready for doffing. When the frame is arranged so that the bobbin leads, these movements are reversed.

Ordinarily, the product of this frame is rove only; but it is customary, when the yarns required do not exceed 400 yd. to the lb., to finish the operation in this frame, by giving the material the amount of twist that is necessary to impart the requisite strength, and constitute it yarn. By this means, one process is dispensed with.

Spinning.—The bobbins containing the rove are next carried to the spinning-frame, in which the latter is attenuated for the last time to any required degree, and receives the complement of twist which renders it yarn. Fig. 871 shows a section of this machine, which, in its essential parts, is the "throstle-frame" of the cotton trade. The details of size, &c., depend upon requirements; but, for the average of jute yarns, a frame providing 128 spindles, 64 on each side, may be considered of full dimensions. These are arranged in a single row, the pitch or distance between them being 3¾ in. A rack or creel, possessing as many pins as there are spindles in the frame, is supplied with the bobbins *a*, containing rove from the last frame. The strand of rove is conducted through an eyelet-guide *b*, to the retaining-rollers *c*, between which it passes to the binding-plate *d*, and over the conductor *e*, to the drawing- and pressing-rollers *f f'*, through the thread-plate *g*, and around the leg of the flier, whence it passes upon the bobbin *i*. The retaining-rollers *c* are fluted, and thereby retain a more firm grip of the rove. As the latter is attenuated by the drawing-rollers, it is slightly condensed by its passage over the binder-plate and conductor. The drawing-roller *f* is made of iron, and the pressing-roller of wood, the latter being held in position by steel springs. The attenuation of the rove is accomplished by this pair of rollers being made to run at a considerably greater surface velocity than the retaining-rollers: the higher the velocity, the greater is the attenuation, and the finer the yarn. The differences in the relative speeds are obtained by change-wheels, to suit the size of the yarn required. The rove containing only one turn of twist per inch, when subjected to a draught of seven, almost loses its power of coherence, and would probably break, were it not for the service rendered by the binder-plate, in consolidating the somewhat loose form of the fibres, and the assistance of a similar kind derived from the conductor, whilst the rove is on its passage to and through the drawing-rollers. Immediately on emerging from the nip of these, it is twisted strongly by the rapidly-revolving spindle, which fixes it in the form it has to retain as a thread, and so completes the first stage of the manufacture. Maintaining the assumption that the rove was 294 yd. to the lb., a draught of 7 would yield a yarn of 2058 yd. to the lb., less the small proportion that would be taken up by the twist which is imparted to the strand.

871.



For the foregoing illustrations, and much valuable information, indebtedness is acknowledged to W. Fleming, of the Barrow Flax and Jute Works, and to the Institute of Mechanical Engineers.

Jute yarns receive their denomination from the weight of the "spyndle," which contains 14,400 yd.; such a yarn as has been assumed to be passing through the series of machines described above would give 7 lb. to the spyndle, and hence would be known as "7-lb. yarn." The range of weights of yarn extends from 1¾ to 30 lb. a spyndle.

Jute yarns, as such, are used for many purposes: twines, cords, ropes, covering telegraph-cables, wire-ropes, &c.

Manufacturing.—Having traced the raw material through the processes necessary to form it into yarn, it only remains to describe the weaving department, or the operations necessary to convert it into a textile fabric. As compared with the preceding, these are comparatively unimportant, and vary but little from the processes followed in other branches of weaving.

Jute differs from most other textile fibres in being capable of use in the "green" or unsized condition for most of its purposes, though the finer Nos. of its warp yarns are usually sized.

The calculations for the manufacture of jute in the weaving department are based on the following table:—

90 in. = 1 thread = 2½ yd.
120 threads = 1 cut = 300 „
2 cuts = 1 heer = 600 „
6 heers = 1 hasp = 3,600 „
4 hasps = 1 spyndle = 14,400 „

This means that jute yarn is reeled on a reel of 90 in. circumference, and 1 rev. forms a thread; 120 threads are tied together, and make a cut; and so on throughout the table. As observed above, the fineness of the yarn is determined by the weight of the spyndle, and is spoken of as 6-, 7-, and 8-lb. yarn, or otherwise, as the case may be.

Jute fabrics are described by the number of "porters" and width in inches, the length being according to requirement. As an illustration, take say a "16-porter 40-in. Hessian, of 18 "shots" or picks per inch and 100 yd. in length. The porter is the standard in jute manufacture by which the fineness of the "camb" (or set of heddles) and the reed are determined, and consequently the number of threads in the warp to make any given description of cloth. The porter is composed of 40 heddles, each heddle containing one thread, and 20 splits or dents of the reed, two threads going between each two dents. When one thread alone is used, the reed is as fine again. The number of porters in 37 in. of the reed indicates the fineness of the cloth. In the case supposed, it occurs 16 times, and so gives its denomination to the web. The texture of a jute fabric is, however, considerably modified in the finishing process to which it is subjected. This consists of heavy calendering, by which the length of the piece is increased at the expense of its width, and by means of which it may happen that the latter is so much contracted that, though woven as a "16-porter," it could only be accurately described by calling it an 18-porter fabric.

When the particulars of a cloth which it is intended to make are found, the necessary instructions are given to the warper. On 37 in., 2 in. are allowed for shrinkage in width, and 10 per cent. for what is taken up in the length owing to the warp threads being deflected from a straight line by the insertion of the weft threads. This amount is not invariable, being larger when the weft is coarse or heavy, and less when very fine.

Warping.—In establishments in which both spinning and weaving are carried on, the bobbins from the spinning-frame are often taken directly to the warper, and the cost of winding is thereby avoided. The bobbins are placed in a "bank" or creel, and sometimes, when the fabric is very narrow, and the creel will contain a sufficient number of threads, these are run direct upon the weavers' beam, if it is intended to be used in the green state. When the warp requires a large number of threads, it is divided into four parts, one quarter being warped at a time, the four parts next being run upon the weavers' beam. This process is generally regarded as the most expeditious and economical in making wide warps, as the small number of threads enables the warper to give them perfect attention, and, at the same time, permits the speed to be considerably increased. The warping-mill employed in the jute trade is the common vertical reel mill, composed of an upright beam revolving upon two iron pivots, one at each end. Into this beam are inserted three rows of arms: one each at the top, centre, and bottom. Vertical bars of wood are fixed upon the extremities of these arms, and the whole composes the reel. At the bottom of the central beam, is a pulley, around which passes the driving-band from a larger pulley outside the reel, whereby it is driven. Owing to the comparatively short length of jute warps, and the frequent stoppages that occur in making them, it is customary to use manual power instead of steam, though the latter may be at hand. The warping-mill is therefore worked by means of the hand and foot of the attendant. The yarn from the banks or creel, being passed through two reeds, is attached to and wound spirally upon the reel, the length of the warp depending upon the number of turns of the reel before its action is reversed. The breadth is decided by the number of threads in the bank, and the number of "bouts," as a complete traverse of the winding process over the reel is termed. When the warp is completed, before it is "doffed," or removed from the mill, a "lease" is taken, which means that the threads have to be alternately elevated and depressed, to admit of the insertion of a transverse thread, to facilitate a subsequent process. In order to permit this to be done with facility, the two small reeds employed to conduct the threads from the bank of bobbins to the reel are utilized. The reed nearest the bank is constructed in the usual open way, but the second has every alternate split stopped with solder at about 1 in. from its rim, by which means the threads are instantly separated as desired. The doffing constitutes a chain, warp, or section of a warp, as the case may be.

Beaming.—The next process is "beaming," or winding the warp upon the loom-beam. The sections of the warp are placed side by side, and the threads from each are passed in a larger or smaller number through the dents or splits of a coarse reed, termed an "evener" or "wraithe," by means of which, when the machine is started, the yarn is wound evenly upon the beam, as guided. This evener contains 72 pins in 37 in., and sometimes has a loose top which is removed in order to insert the threads between the pins, and replaced to retain them in position for the winding process. The number of threads put into the spaces between the pins are termed "pinfuls."

Drawing-in.—After beaming, the next process is to draw the warp threads into the camb and the reed. The eyelets of the heddles are composed of wire rings. The "drawing-in" of the warp is a very simple process, accomplished by means of a hook being put through the reed and heddle-rings, which, having the warp threads put over it by a child assistant of the drawer-in, is withdrawn, bringing each thread with it. When all have been thus drawn in, the warp is ready for the loom. This process only takes place when a camb is new and has to be used for the first time. After the first warp has been woven to near the end, it is cut so as to leave a sufficient length behind the heddles, to which the succeeding warp can be tied.

Sizing.—In the case of fine yarns, the processes differ somewhat from these. The bobbins from the spinning-frame are taken to the winder, who winds the yarn upon large bobbins which go to the sizing-frame. This frame is a very simple machine, being almost like the beaming-frame just described, but instead of taking the yarn in the form of a chain, it is fitted with a creel, large enough to contain a sufficient number of bobbins for a complete warp. The threads are passed through a reed, as before, after which they are conducted through a trough of thin size made from farina, on emerging from which, the "sheet" of threads is exposed to the action of several drying-fans, and then passes upon the beam. There is no sizing for weight in the jute-trade.

Weaving.—Jute looms possess no feature to distinguish them from looms employed to weave other fibrous materials, beyond being of increased strength. They are adapted to weave plain fabrics, twills, and sometimes figured goods, as in the case of jute carpets. They are usually on the overpick principle, and of various widths. When contrasted with looms used in other branches of the textile industries, they appear crude and roughly finished, and, generally speaking, it might be advantageous to bestow upon their construction a little more care than is apparently given at present. Owing to the character of the fibre, and the heavy yarns usually spun from it, the looms for weaving jute have necessarily large projections at the end of the lathe for shuttle-boxes to receive the great heavy shuttles employed.

Formerly pirns were used, on which the weft yarns were wound. These were of wood, but were of necessity so large that very little yarn could be put upon them, and the frequent stoppages caused by its exhaustion greatly restricted the production from a loom. A few years ago, however, a machine for forming cops for weft purposes was invented, and has now to a great extent superseded the use of pirns. The yarns intended for weft are brought upon the bobbins from the spinning-frame to the copping-machine. Being placed in the frame, the thread is drawn from the bobbin, and passed through a conical cap fixed upon the extremity of an oscillating lever. The thread is attached to the winding-spindle, and the oscillating cap, which is a hollow cone, traverses the thread in the winding so as to form a cop, which, when doffed, is ready for the loom. The peculiarity of this cop is in its construction, which enables it to be used from the base, the yarn being drawn from its interior. This necessitates a peculiar form of shuttle also, which has no peg, as ordinarily, but is prepared to receive the cop without, and has the open top closed with a metallic plate, fastened down with a spring. By the adoption of this plan, the production has been increased, the quality improved, and the cost lessened.

In jute-weaving, similar qualities are required as in other sections of the trade, to constitute the best results. An even distribution of both longitudinal and transverse threads must be secured; irregularities in the picking must be avoided, and the fabric must not be "reed-raked." "Putting a skin on the cloth," as it is technically called, is an important matter in making a marketable article. This is what is known in the cotton trade as "cover," or throwing upon the surface all the loose fibres of the yarn composing both warp and weft, whereby the fabric appears full and closely woven, or more so than it would otherwise do were this matter neglected. These are points of detail occurring in practice which do not require further reference here.

When the cloth leaves the weaver, in a well-conducted establishment, it is usually examined, and all blemishes are repaired, absent threads through breakages being inserted by the needle. The women to whom this task is confided execute it with great dexterity and swiftness. After examination, the cloth is ready for finishing.

Finishing.—The finishing of jute fabrics consists of little more than calendering. The material has, long before arriving at this point, lost most of the moisture it received in the batching process, and has become dry and rough. In order to render it pliable, and more amenable to the influence of the calendering process, each web is passed through a damping machine; in the body of this is fixed a brush, which, dippping into a trough of water, and rapidly revolving throws a shower of fine spray against the cloth. As the cloth is thus rolled damp, every portion is soon penetrated by the moisture, and it is then ready for the calender.

Calendering-machines are of different forms and sizes to suit requirement. The largest and most powerful are capable of putting a pressure of 100 tons upon the article subjected to their operation. The price of machines of this capacity is 4000*l*.-5000*l*. An ordinary calender consists of four rollers, two being hollow metallic cylinders, highly polished, and heated by steam. These are placed alternately with the other two, which are composed of compressed paper-material, and are extremely solid and heavy. The web being passed through this machine, and thus subjected to great pressure and heat, receives a glazed finish, which considerably alters its appearance. The length is increased at the expense of the width, sometimes to the extent of a porter or two, as indicated above, which consequently alters its denomination as a matter of fact, though the change may not always be made.

There are different kinds of finishes, but, as they chiefly depend upon the amount of pressure given in the calender, they do not require further description. In one or two cases, for special purposes, the fabrics are passed through a shearing-machine, and subjected to the action of a revolving knife-roller, which clears off all the loose fibre of the yarns.

After passing the finishing processes, the pieces are rolled, folded, or plaited, according to requirement, and made up in the most convenient forms for the different markets.

Sometimes the manufacturing processes are carried beyond this point, and coffee-, sugar-, grain-, and other descriptions of, bags and sacks are made upon the establishment where the raw material has been spun and woven. In this case, the fabrics are cut up into appropriate lengths by machinery, stitched by powerful sewing-machines driven by steam-power, piled in bundles, subjected to hydraulic pressure, and packed for sale.

Jute is one of those textile fibres which is capable of very minute subdivision. But for a long time, it proved comparatively intractable in the hands even of the most skilful operators. This confined its use to the most humble domain of the textile industries; the manufacture of sacking, canvas, carpet-backing, and coarse carpeting. A few years ago, however, it began to yield to the efforts made to accomplish the more perfect disintegration of its fibre, which has led to its use in more pretentious fabrics, such as crumb-cloths, table-cloths, towellings, &c. Further success has also been more recently attained, not only in the more minute subdivision of its fibre, but also in bleaching and dyeing it. All attempts to accomplish the former object rendered it weak and brittle, and almost unfit for textile uses; whilst efforts to dye it succeeded merely to the extent of depositing a thin film of colouring matter upon its surface, which slight friction would rub off. In all these points, considerable advances have been made. The fibre can now be divided so finely that it is capable of being mixed with silk, for association with which its natural lustre eminently fits it. The improvements effected in the methods of dyeing have led to the production on it of the most bright, fine, and permanent colours, of lustrous beauty. These results, though practically successful, have hardly yet been commercially so; but it may be hoped that no long period will intervene before even this is achieved.

The progress made in manufacturing jute in this country since its introduction is very remarkable, as will be seen from the following figures extracted from the latest official Returns (1879):—

Jute Factories in the United Kingdom.

	No. of Factories.	Total No. of Spinning-Spindles.	Total No. of Doubling-Spindles.	Total No. of Power-Looms.	No. of Children working Half-time.		Total No. of Persons employed.		
					Males.	Females.	Males.	Females.	Total.
England and Wales ..	12	23,762	1,407	1,057	325	298	1,382	3,579	4,961
Scotland ..	99	183,056	5,855	10,009	1,203	1,674	8,920	21,481	30,401
Ireland ..	6	5,858	230	222	14	8	272	720	992
Total ..	117	212,676	7,492	11,288	1,542	1,980	10,574	25,780	36,354

The numbers of persons employed, the capital invested, and the value of the manufactured product, fully demonstrate that, though one of the youngest of the textile industries, it bids fair to attain considerable importance. R. M.

KNITTED FABRICS—HOSIERY (Fr. *Bonneterie*; Ger. *Strumpfwaaren*, *Wirkwaaren*.)

The adoption of coverings for the nether limbs was undoubtedly one of the latest developments of the clothier's art. By what people the custom was first introduced, is not known; and it is equally uncertain what material was first employed for the purpose. As various causes compelled some tribes of the human race to wander into temperate and cold regions, they must have found that the partial covering, which had previously sufficed for their requirements, no longer served to shield them. Hence those parts of the body which had hitherto been left uncovered, such as the arms and legs, would receive equal attention with the other portions. It is a probable conjecture, therefore, that "hose" originated with some of the nations residing in the northerly temperate latitudes.

The material first used would most likely be the skins of the smaller quadrupeds, including those of kids and lambs, to be succeeded in time by cloth of different materials, when the art of weaving had made some progress. Hose made from woven fabrics remained in general use until comparatively recent times. Woollen cloths being common, and possessing other merits to recommend them, were most naturally adopted for this purpose. Plenty of evidence exists to show that hose of this description was in general use down to the close of the 16th century, when it began to be superseded by the knitted article, which, from its superior adaptability, after its introduction, soon won universal favour.

When or by whom knitting was invented, is not known, but in manuscripts of the early part of the 16th century, are occasional references to knitted hose, whose prices indicate that the art was then a rare accomplishment.

Of the origin of machine knitting, we have more definite particulars. The hosiery industry, as we know it now, is indebted for its existence, and probably for its remarkable development, to the inventive genius of a clergyman, William Lee, of Calverton, near Nottingham. His struggles in perfecting his invention appear to have almost exhausted his means before the idea received practical embodiment. Even after this was accomplished, success was far from complete. His unsuccessful endeavour to obtain the patronage of Queen Elizabeth is well known. Encouraged by promises from the King of France, he subsequently emigrated to that country, and settled at Rouen, where he endeavoured to plant the new industry. Here misfortune still followed him: his patron, Henry IV., being murdered, all his hopes of protection and favour were destroyed, and, under increasing difficulties, he died in Paris in 1610, in a state of indigence. Subsequently, his brother James brought the machines back to England, and settled in London, where the new art soon made considerable progress. The industry grew to such an extent that, about 1650, its members had become so numerous, wealthy, and influential, as to make efforts to establish a chartered company. Another motive inducing them to take this step, was the difficulty the unchartered company experienced in enforcing regulations, devised to prevent unfair competition amongst its members. These objects were realized in 1657, by the grant of a charter from Cromwell. A second charter, confirming the first, was afterwards obtained from Charles II.

It is not necessary here to trace the steps by which Lee perfected his machine, nor to detail its subsequent development in the hands of later inventors, in more than brief outline. Few were of much importance, until Jedediah Strutt added the ribbing-apparatus, in 1758. This invention enabled a ribbed web to be produced on Lee's machine, which had hitherto been able to make only a plain one, except by hand, by selecting the threads and arranging them in order to form the pattern. Derby ribbed hosiery soon raised itself into high and extensive favour, and the principle is as popular to day as ever. Strutt's invention was followed by the improvements of Morris, Crome, and Else, which, with others, laid the foundation of the modern machine-wrought lace. The success attending the labours of Strutt, and the wealth secured by several individuals who adopted his improvements, greatly stimulated invention, and the patents taken out during the remainder of the century were numerous and important, much advancing the perfection of the machinery. An enumeration of these would be uninstructive, unless accompanied by full explanatory details, and, for this reason, they are mostly passed over. The most remarkable feature developed was the great capacity for the manufacture of fancy hosiery, which, as a consequence, became exceedingly popular. The demand for this class of goods endured until the close of the century, when the fashion began to decline in public estimation, until a point of deep depression was reached. Great sufferings were consequently entailed upon the workers for many years afterwards, a revival seldom being more than partial or temporary.

This depressed period did not terminate until subsequently to the year 1845, when considerable changes were introduced into the machinery employed in the trade, circular frames taking the place of those previously existing. A more important movement was the adoption of the factory system of employment, by which a better organization of labour was effected, and habits of steady industry were fostered, the development of which have carried the hosiery trade to its present high prosperity, as one of the best paid industries in the United Kingdom.

Depression and low wages constituted a great obstacle to the introduction of improved machinery, by which further reductions could be made in the price of the finished article, and the consumption be correspondingly increased. At the above-mentioned date, however, a considerable number of new frames, working by steam power, and yielding a much larger production, had been got to work with beneficial results. The great change in the commercial legislation of the country, which was inaugurated by the repeal of the Corn Laws, and the subsequent abolition of nearly all import duties, was near at hand, and this transformation took place just in time to meet the greatly improved demand, which the stimulus derived from a liberated commerce gave to the trade.

Some difficult problems in connection with the improved machinery remained to be solved, such as the shaping or fashioning of the fabric by automatic means, and without the cessation of its action. Barton, an inventor, partially accomplished this, by a plan in which the stitches were shifted automatically, in addition to the movements previously necessary, in a frame known at the time as a "wide rotary frame." In 1816, Sir Marc Isambert Brunel invented a circular knitting-frame of considerable merit, which has since been rendered most effective and useful. This machine, Brunel called the "tricoteur," or "frame-work knitter"; it produced a tubular web, which was cut up and finished by subsequent operations. The general aversion at that time to unshaped hose, however, caused it to be neglected, and it passed out of notice until about 1844, when Pagets, of Loughborough, reintroduced it, with modifications which greatly increased its value. It was further improved by Peter Claussen, of Brussels, who took out a patent in this country in 1845, and exhibited his machine in Nottingham. The manufacturers of that town, though strongly averse to the introduction into the trade of the "leg-bag" machine, saw that further opposition would be unavailing, and that if not adopted there, it would become a formidable competitor elsewhere, yielded in detail to the force of circumstances. Claussen, in 1847, added further improvements, rotating hooks and a winding-up apparatus, which practically perfected the machine, as without these, the rapidity of its production of tube-web rendered the latter an encumbrance. After this addition, the adoption of this class of machinery extended rapidly. The "wheel frame" was soon afterwards introduced, and so-called because "the operations of supplying the yarn, dividing the loops, pressing them, and carrying them over the heads of the needles, are accomplished entirely by means of wheels." This mode of constructing and manipulating round machines continues to be most prevalent for making plain circular stocking-web. The cylinders have been increased greatly in diameter, so as to adapt the production to other purposes. Notwithstanding these changes, there still remained to overcome the initial defect of this class of frames. The product was a tube of equal diameter throughout: a "leg-bag," as it was contemptuously called by those who produced shaped hosiery. But about this date, an invention was perfected by a framework knitter, named Thompson, by means of which, the circular frame was enabled to produce ribbed hose, which, from its peculiar texture, conforming readily to the outline of the leg, dispenses with all necessity for "shaping" or "fashioning." This improvement opened a wide field of usefulness to the circular machine, and gave a great stimulus to the trade.

In 1847, M. Townshend, a framework knitter, patented the first of a series of great improvements, to which the trade has been much indebted. The first was for the adaptation of a machine like a point-net frame, to an ordinary stocking-frame. This invention was intended to take the work by the machine off from, and return it to, the frame instruments, in such manner that the direction of the loops might be reversed on the surface of the fabric from time to time, as it was effected by hand knitting, and by frames which were reversible by hand. In 1854, Townshend invented a plan for making round hose on the circular frame, the heels and toes being fashioned on other machines. Two years later, he came forward with another improvement, a method of raising looped pile on knotted fabrics for "terry." This he accomplished by employing a row of needles or points, or their equivalents, acting in combination with a jacquard apparatus. Using a bell crank and lever guides, similary actuated, for throwing different colours into the work, and using "hinge covering needles" in knitting double pile fabrics, and a notched sinker. In the same year, he took out another patent, in which these hinge covering needles are again employed, and probably in a more perfect form. The patent was for the application of jointed guides to the machinery of double barred knitted goods, so making figured patterns on both sides, which he accomplished by throwing threads on one row of needles or hooks, to form the pattern, and carrying surplus threads round the other row of needles, to form the pattern on the reverse, the result being that both sides appeared alike. Sliding needles or hooks were used, moved by the jacquard in the required direction. In this invention, rows or circles of double-ended needles, having hooks or beards at both ends, were introduced, and formed loops by a peculiar method. He also claimed the making of circular knitted warp fabrics, by using a row of "tumbler" needles, having hinged beards circularly placed, with lever guides to carry the threads forming the fabric.

This "tumbler" or "latch" needle has since become an important feature in many machines constructed for the manufacture of fancy hosiery. It is now in extensive use, in this country, as well as on the Continent, and in America, to which last country Townshend subsequently emigrated.

Thompson, whose name has been mentioned, in 1853, took out a further patent for improvements in looped fabrics, made upon the circular ribbing-machine, in conjunction with Hine, Mundella, and Co. By this improvement, the thread from the cop was carried under the frame needle beards by a looping-wheel. As these needles were carried around, they were depressed by the lower part of the collar, thereby bringing their beards to the frame-presser; after pressing, the work was pushed over by the top of the collar. The work was next drawn back ready for the machine-presser to operate upon it, at which position, a plate drew the machine needles back, and the work was pushed over, the frame needles rising and the machine needles being thrown out, which completed the course.

In 1854, Luke Barton improved the stocking-frame by the application of a narrowing apparatus, and patented the improvement in conjunction with Hine, Mundella, and Co. Both frame and attachment were actuated by rotary motion. Up to that time, only one or two hose of fashioned quality had been made in their widest parts on one machine; but by this invention, from two to ten hose were enabled to be made at once, with less labour to the workman, at less cost, and with a greatly increased production. The invention was also applied to the manufacture of other articles, as shirts, drawers, half-hose, &c.

Several minor inventions, but of a useful character, were brought out under the auspices of the same firm, and also by other individuals. Amongst these, may be mentioned one by Mowbray, of Leicester, which was an arrangement by which a stocking-frame was rendered capable of widening or narrowing at will, by the application of a jacquard apparatus. This plan has been used extensively by the Leicester manufacturers, it being better adapted for the woollen hosiery trade than for cotton and merino, of which the Nottingham trade chiefly consists.

The next inventor who has left an important impression upon the trade is William Cotton, of Loughborough, whose first patent was taken out in 1851, for the widening of the fabric by the action of the machine working upon rotary power. In 1860, he added an arrangement by which it was rendered capable of narrowing as well as widening. In 1863, he effected further improvements on the above, rearranging the parts so as to place them on a horizontal plan, instead of a perpendicular one, as previously. The widening and narrowing processes are accomplished by the action of ticklers, having one or more points in each, and which are placed on a movable rod so ingeniously and accurately adjusted as to obey a side movement either way, to the extent of the distance of one needle only, whatever may be the gauge, and to take off, remove, and put on to the next needles, any number of stitches required. The narrowed selvage was perfect; the widened one, though not so good, was sufficient for the purpose.

A notable improvement in hosiery machinery was contributed by W. C. Gist, an American, who took out an English patent in 1858 for a circular machine, to be supplied by any number of feeders up to eight, where only one had been worked before. This greatly increased the productive power, and enabled striped work, containing up to 16 colours, to be made at once. With a head of 12 in. circumference, 350 courses, or 1 yd., can be knit in a minute, which is equal to a length of web sufficient to form 150 doz. of women's hose in a week. Hine, Mundella, and Co. secured the patent-right of the machine in this country, and while in their hands, it was simplified and improved by Thompson, the inventor of the circular rib-frame. Thompson replaced the ordinary needle by Townshend's tumbler-needle, and the improvement was so manifest as to secure its immediate and extensive adoption in the Leicester trade.

The name of Moses Mellor is a distinguished one in the annals of invention connected with hosiery machinery. In 1844, Mellor improved Brunel's round stocking-frame, by placing the needles perpendicularly, instead of in a radial horizontal circle, and operated on them outside by an indented loop-wheel roller. Still further to secure an equal division of the loops, in 1849, he added a second wheel of the same kind to follow the first. In the same year, he devoted his attention to the wide power stocking-frame, into which he introduced a thread layer, by which the yarn was placed between the needles where the selvage had to be formed, without disturbing them, thus dispensing with the plan of raising them out of the way. In 1863, Mellor invented a series of modifications of the round stocking-frame, by which he was enabled to produce plain, striped, and fashioned fabrics. In the same year, he secured a patent for an invention to be applied to a reciprocating straight-bar frame, making one or more breadths at once, or to a reciprocating circular frame making one or more breadths at once, by the application of which, was produced a fabric either plain, or ribbed in one part and with loose loops on the other part, the patterns varying according to the setting of the machine. In 1863, he also constructed a wide or longitudinal fashioning rib-frame. This invention, which increased the production more than tenfold over the original Derby rib-frame, he threw open to the trade.

In conjunction with Edward Attenborough, W. Cotton patented further improvements in 1869; these consisted of a better general arrangement of the parts of the frame; the construction of the thread-carriers of steel, so that the points or feed-ends might bear upon and more readily follow the course of the traverse provided for them; and a tension arrangement for tightening the threads when passing to the carriers, in making the plain or unfashioned portion of the fabric, when the thread-carriers were at the end of their traverse, and the loops were being divided. For this purpose, each thread was made to pass between a spring, and an arm with capability of varying—increasing or diminishing—the pressure by stationary wedge-pieces or similar means in the forward movement of the arms and springs. Extra motion was given to the shifting instruments, when they were moving for widening, proportionate to the extra strain upon them at such a time, so as to secure their standing correctly in position for the laying of the loops on the needles to which the loops were being shifted, and similarly in relieving such extra movement for narrowing. Means were likewise provided for filling up the holes otherwise left by the action of separating the loops for widening. The inventors improved the presser-bar by introducing a rib of steel into a groove in the edge of the presser, which obviated a great portion of the wear so common when the bar is composed of soft metal. Increased capability of adjustment of the movement of the needles in relation to the sinkers, so as to be able readily to vary the stiffness of the fabric during working, was also obtained; and a further arrangement was introduced, whereby the movement of the thread-carriers was controlled at the termination of their traverse, by means of which, it was ensured that the thread at such times should be taken between the desired sinkers, thereby avoiding the production of bad selvages.

In 1879, Thomas Wigfield patented a method, by means of which, he claimed to produce fashioned and cleared fabrics of varying width, less than the breadth of needles, and by employing two thread-carriers and carrier-slides, by the same means to produce selvaged heels; and instead of taking away portions of the jack- and frame-sinkers, and frame- and machine-needles at each division, to produce such fabrics by employing the apparatus of which the invention consists.

About 1877, an American, Almet Reid, patented in this country an ingenious circular knitting-frame, capable of automatically knitting articles of every variety of shape, such as hats, caps, Scotch bonnets, and bags. Its principal features consisted in its having the equivalent of a Jacquard motion attached; in the capability of knitting simultaneously a greater number of threads than ordinary circular machines; in the fact that goods produced in it are composed of loops or stitches, so locked together that, in the ordinary way, they will not unravel when cut or torn; and lastly, a rate of production considerably exceeding that of ordinary knitting-machines.

The patent-right of the above machine was acquired in this country by a joint-stock company, and under its auspices, the principle of the above invention has been applied to a straight machine. As constructed, this has been brought into public notice as the "straight-bar knitting-loom." It is not complicated in its parts, nor as a whole; and can be made of any width. As it is designed to produce piece-goods, it requires to be 70–90 in. broad for wide descriptions. The needles are set on the bar, which may be of any required gauge. A loom 72 in. wide, 9-gauge, contains 6 needles to the inch = 432 in the width. The needle-bar has imparted to it a rapid vertical motion, of short stroke, during which, the needles rise and fall in front of and close to a bar perforated with holes, one for each needle. Through these holes, the yarn is passed, one end in each being delivered from bobbins or a beam, as may be most convenient. Each time the needle-bar rises and falls, every needle makes one loop, and the texture is thus produced simultaneously along its whole width. Each course of loops is drawn away by a thin blade called a "wiper," possessing a reciprocating action. A pair of fluted rollers receive and pass the cloth down in front of the machine. The number of loops put in the width naturally depends upon the number of needles in the bar; but without altering the gauge of these, the openness of the fabric can easily be varied, by altering the stroke of the needle-bar, and the rate at which the delivery and taking-up rollers operate, this being easily done in a few minutes. This variation is easily extended from 4 to 24, or any intermediate number of loops per inch, in the direction of the length of the fabric. The loops are effectually locked together, even those that form the selvage. The production from this machine is extremely large, the driving-pulleys actuating the main-shaft, making 200 rev. a minute, with the result that each needle makes a similar number of loops or meshes. The length produced depends upon the size of the mesh; with these 13 to the inch, working at the above rate, it produces about 15 in. of web a minute. At this rate, its production is equal to that of 10–12 ordinary power-looms, weaving woollen cloth of the same width. Upon this machine, the yarn can be used unsized, and softly spun, or containing little twist, one of the advantages claimed for it being its capability to work up soft or tender yarn unfitted for use in the ordinary loom. It is also capable of making stripes, either plain or "herring-bone," or combinations of these; but it is not in this direction that it will ever prove a formidable rival to the ordinary loom.

This brief review of the development of the machinery of the hosiery trade brings us to the present day.

Hosiery, as generally understood, and as considered here, is a production of the art of knitting—a subdivision of the greater art of weaving. It is a process by which a series of loops are made to intersect each other, the aggregate forming a web. It can be executed by hand, by machines wrought by manual power, and by others in which steam is employed as the motor. An expert operator by hand can make about 100 loops a minute; by manual power, this number is very largely increased; whilst in some modern machines worked by steam power, more than 300,000 loops a minute can be produced.

Hand knitting is now rarely practised as an industry, or a means of obtaining a livelihood. Here and there, in secluded districts, such as the Highlands of Scotland, some parts of Wales and Ireland, and similarly in many parts of the Continent, the peasantry follow the practice in the intervals of more laborious occupations, and by its means add some little to their earnings.

Machine knitting by manual power, though still followed to a considerable extent, is a decaying industry. The hand-machine is used chiefly for the production of what is termed "fancy hosiery," of elaborate or variegated patterns, such as it is difficult, if not impossible as yet, to produce by automatic machinery worked by steam power. Where it is still used as a competitor with the latter, it is retained at a great disadvantage, because the operator has to bestow his strength and attention upon the working of the machine, whilst it would be more profitably exercised in superintending a greater number actuated by steam power.

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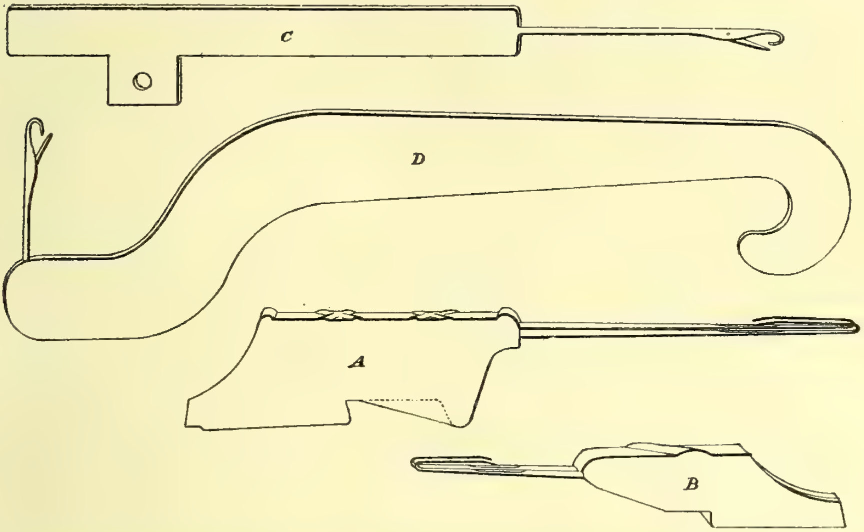

The essential part of both manual and steam-power machines is the needle. Of these, there are two kinds, as shown in Fig. 872. A B represent the one invented by Lee, but in the perfected form to which modern scientific mechanism has brought it. It consists of the shank, the hook, and the beard or returned point of the hook. Underneath the beard, a groove is cut in the shank, for the reception of the former when pushed down by the presser-bar or wheel. This is the needle in most general use. Those marked C D are latch-needles, a much more recent invention, and the use of which has led to important changes. Both sorts are shown as mounted for the machine. The manual stocking-machine has a framework of wood, on which the working parts are supported. In front is a seat for the operative. The yarn is supplied from a bobbin conveniently placed. The needles are arranged horizontally, as in Fig. 873. The chief parts are the sinkers *f*, locker *g*, jacks *h*, needles *i*, slur-bar *l*, slur *m*, pulley *n*, and locker-bar *p*. These constitute the parts of the machine as Lee left it: of sufficient capacity to make a plain looped fabric. Jedediah Strutt's improvement, by which a ribbed web was enabled to be produced, consisted of the addition of a second series of needles *c*, Fig. 875, mounted on a lever *e*, and jointed to a vibrating arm *f*, attached

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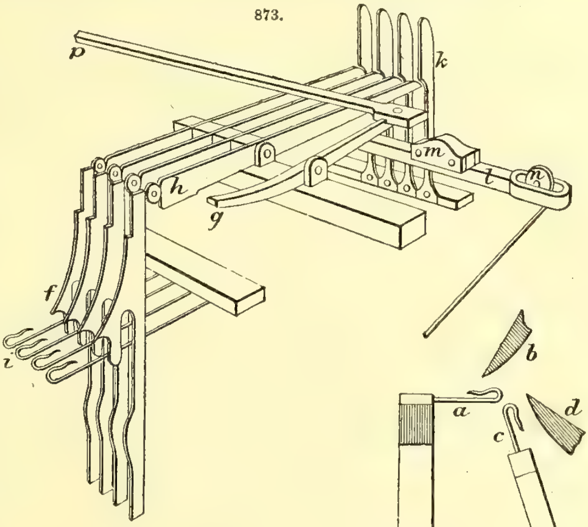

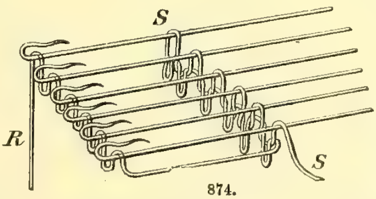

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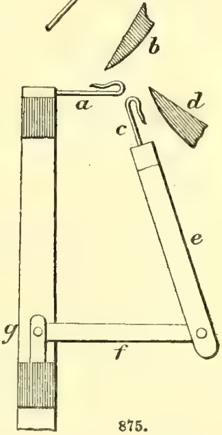

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to the standard by a pin on which it is free to oscillate. There are three treadles to the manual frame, placed conveniently for being actuated by the feet of the operative when at work. Two of these are connected with the jacks by means of cords passing around pulleys, placed in the centre of the frame, and the third is similarly connected with the presser, the attachment being made at the extremity of an arm, which projects towards the back of the frame.

There are two classes of sinkers, bar- and jack-sinkers; each of the latter, which are arranged alternately with the others, are attached separately to the end of a lever or "jack," and by means thereof can be depressed separately. It will be observed that the sinkers *f* are arched in the middle, so as to form a hook, and beneath this hook there is a projection. These sinkers having to pass easily, and very quickly, between the needles, are made with great exactitude, being blocked out of thin sheets of iron, and carefully finished by polishing, so as not to injure the threads in working. All parts of the frame require to be finished with the greatest accuracy of detail and perfection of workmanship.

The mode of operation and the action of the machine is as follows:—The thread is drawn across the needles in contiguity to the arch of the sinkers; the jack-sinkers are depressed by means of the treadle, which action forces the yarn down between alternate needles; the jack-sinkers are raised; then both frame- and jack-sinkers are depressed to half the depth of the first movement, the yarn being by this means equally sunk between all the needles. The sinkers are next advanced, and carry the yarn in the form of the wave line beneath the beards of the needle, as shown in Fig. 874. To simplify the description, it is assumed that two courses of loops have previously been formed, as shown at S. The last course will be in the arch or hook of the sinkers, and as the latter advance whilst the presser has closed the needles by compressing the beards into the grooves, the previous course of loops is carried over the heads or hooks of the needles, and placed upon the loops which the latter contain. The loops in the needles now form the top course of the fabric, which by means of the hook on the sinkers is then drawn back, to allow the process to be repeated. When the thread has been sunk between the alternate needles by the jacks, and it is required to sink it also between the remainder of the needles, the frame-sinkers must be depressed one at a time, which is accomplished by means of a cord from the treadle-pulley, by which the slur is drawn backward and forward as required. By this means, the thread is sunk progressively across the series of needles, which movement must be completed in the straight frame before the sinkers advance and carry the thread into the hook of the needles.

The thread is supplied in a continuous length from a large bobbin, but it will be evident that the substitution of different kinds or qualities during the progress of the work can be easily accomplished according to requirement. The width of the web is also varied as may be needed, according as the thread is carried over a greater or less number of needles of the series. A stocking-web is thus shaped or "fashioned" in its different parts, before it is sewn or looped together in a subsequent stage.

Such is the simple process of forming a looped fabric, which is essentially the same in all machines. A single thread may be used as described, or a considerable number, called "feeders," as in rotary machines, by which the production is enormously increased. Or, a thread may be used to each needle; when this is the case, the bobbins are arranged in a creel, or if preferred, the yarn is put upon a beam.

By means of a pin or hook, the loops upon one needle may easily be transferred to the next, or even a more distant one, without detriment to the fabric. Advantage has been taken of this to form patterns of great variety and beauty. So made, the product is called "lace hosiery," and though not much in vogue at present, it has formerly been very popular. A pin or point, called a "tickler" needle, fixed in a small handle, is used to effect the transfer.

Tickler-points have been introduced into machines in equal number to the needles. In these cases, they are arranged in a movable bar opposite the hooks. By advancing the bar, the needles are inserted into the loops; being then raised and moved to the right or left, which is called "shogging," they deposit the loop upon the needle adjoining, or such other as may be required for the pattern.

Besides tickler needles, other descriptions can be used with advantage. Strutt's invention was of this character, being the introduction of a second series of needles, by which the loops from any desired number of needles could be reversed, and narrow or wide ribs be made, from which the attachment received the name of the "Derby rib machine."

Nearly all classes of looped fabrics are now made with facility on the improved machines which are worked by power, and by which the production is largely increased, prices are lowered, and the consumption is greatly stimulated. Though hosiery goods are now obtained at lower prices than at any former time, yet the operative hosier earns more money than probably at any time in the previous history of the trade.

The following illustrations, for which, indebtedness is acknowledged to Blackburn and Attenborough, of Nottingham, will serve to show the present construction of the best hosiery machinery now being made.

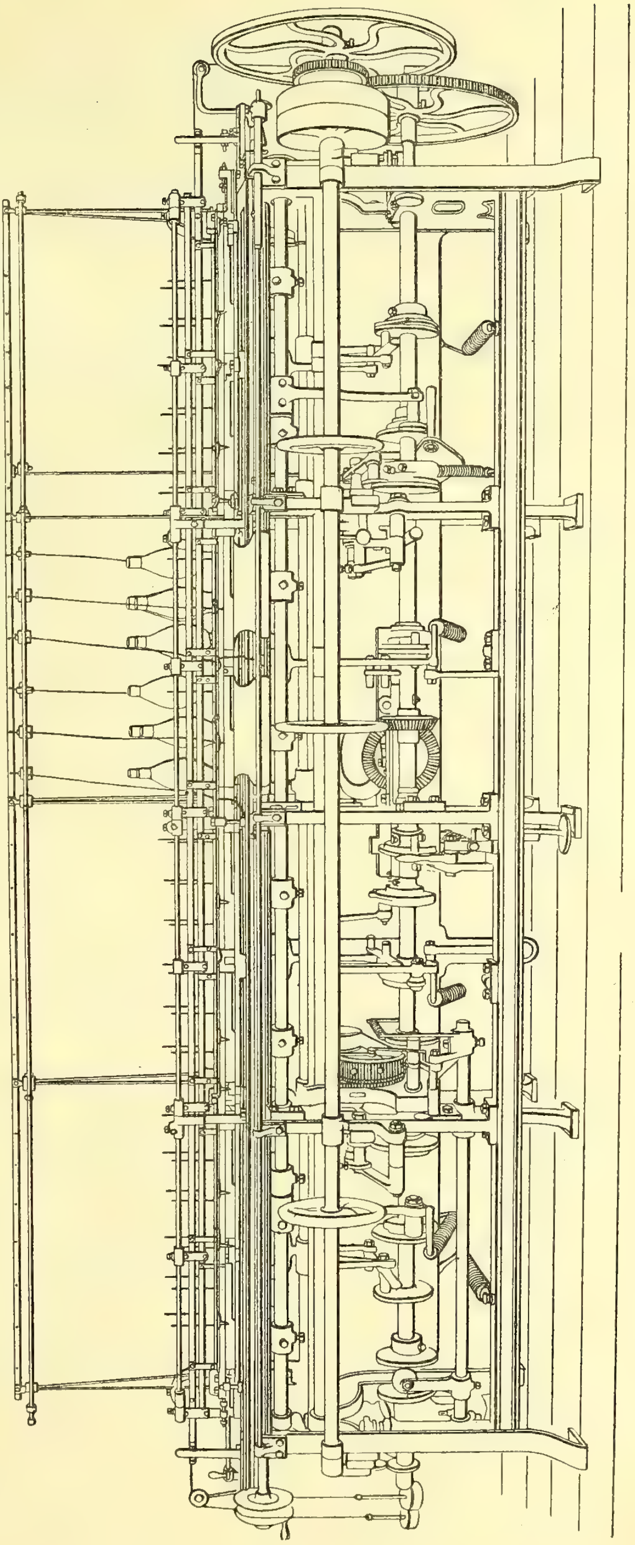
Fig. 876 is a representation of Cotton's self-acting, fashioning hose-machine, which fashions the leg and makes cleared fashioned heels. The frame is generally constructed to produce eight webs at once, two in each section, as shown. All the movements are automatic, and in principle are the same as previously described. Making a 30-gauge web, and working 54 hours a week, an average production of 70 doz. pairs of hose is easily obtained on two machines by a man and a boy, whilst with extra good superintendence, 80 doz. is possible.

It is well to premise here that stockings are not usually completed on one machine, the ribbed top being made on one frame, the leg on another, and the foot on a third, the different parts being joined subsequently.

A footing-machine is made on the same principle as the preceding, and when constructed to make 18 feet at once—the usual dimensions—with one man superintending, assisted by a girl to run the heels and insteps upon the transferring or running-on bars, it will average a production of 100 doz. pairs of feet a week, working on the same gauge, and the same number of hours a week as the preceding, with a possible 120 doz.

This machine, though the term of its 14 years' patent right has nearly expired, with the numerous improvements that have been added, is still by far the best in the market for fashioned hosiery goods, no competitor coming near it in the estimation of the trade. Its price, including the royalty to the patentees, is about 250*l*.

The same machine, with the necessary modifi-



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cations, is used for making men's fashioned drawers; and two of them, each making four at once, superintended by a man and a boy, in 54 hours produce 26 doz. pairs. For shirt-bodies, and fashioned sleeves, it is equally well adapted; two of them, each making four at once of the former, will produce 40 doz. as the result of the above number of hours' work; or 70 doz. fashioned sleeves in the same time. In addition to making plain or fashioned goods, as described, with the patented improvements or attachments held by Lamb and Lee, of Nottingham, they are capable of making odd or even courses, irregular striped work, cheviones, fancy welts with spliced heels, knee-caps, and the seats or pockets of pants or drawers; also 3–4 end stripes.

The ribbed tops of half-hose, bottoms of drawers, and sleeves of shirts, are made separately from the other portion of the fabric, and, in the common sorts, are subsequently attached by a sewing-machine; in better goods, they are ingeniously united by a modified knitting-frame or turning-off frame. Fig. 877 gives a view of the automatic, rotary, rib-top frame. It is entirely self-acting, making the welt, and the slack course by means of which the top is joined to the other part, and putting in the splicing-thread, which, when withdrawn, separates the tops from each other. It is also adapted for, and much used in the production of, striped goods, the stripes obtained being in the direction of the width, not the length, of the fabric. It contains two sets of the bearded needle previously described. It is made in 4, 6, 8, or 12 divisions, and, in the larger size, is capable of producing 300 doz. tops in 54 hours.

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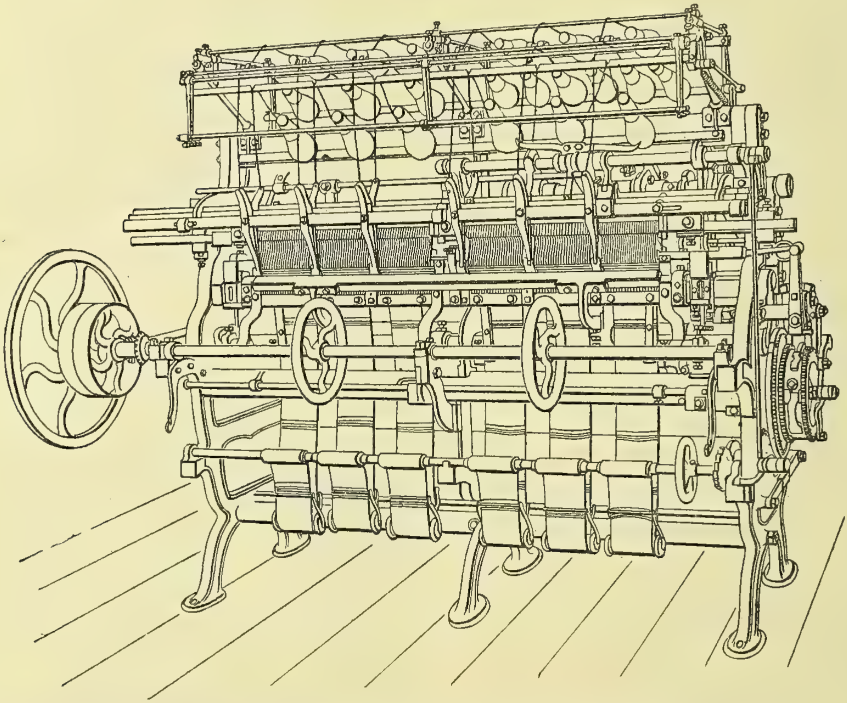

Cheap hosiery for the million is made on the circular stocking-frame, Fig. 878, whose power of production is very great. In this machine, the tube web is woven sufficiently long to form a pair of hose, and is subsequently cut in a peculiar manner to form the foot, and finished by being sewn up. The machine is usually constructed with 12 heads, and is tended by one person. In a day of ten hours, it is capable of producing 1000 stockings, or, with fairly good superintendence, 250 doz. pairs a week. Of this description of hosiery, some of the large Nottingham firms manufacture 25,000–30,000 doz. a week. It is an exceedingly simple machine, requiring no skilled labour, and, on that account, better fitted than most others for introduction amongst populations whose mechanical aptitude and skill are comparatively undeveloped. As a consequence, it is the one most usually exported. At present, it is used extensively in Russia, Spain, and other parts of the Continent, and in America, and India.

Another important machine is the broad-ribbed circular stocking-frame, Fig. 879. This knits any size of rib. It contains two sets of the "tumbler" or "latch" needles, to the invention of which, allusion has been previously made. This needle is shown in C D, Fig. 872 It differs from the bearded or common needle in the manner in which it is closed, to enable the formed loops to be passed over its head. For many purposes, it is an important improvement upon the bearded needle, and its use enables the presser-bar or wheel, as the case may be, and the mechanism necessary for working them, to be dispensed with. The shank of the needle near the hook is flattened, and divided for the reception of the latch, which is retained by a pin on which it oscillates. When the hooks have received their course of thread, being drawn down the preceding course which is upon the shank, the latch is pushed up, and the hook is closed, which enables the

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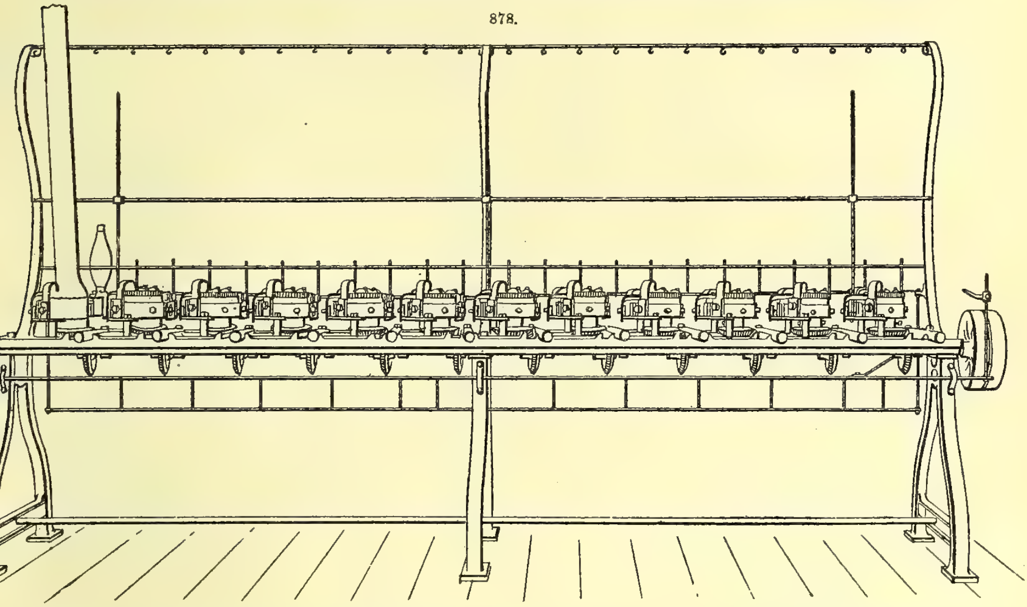

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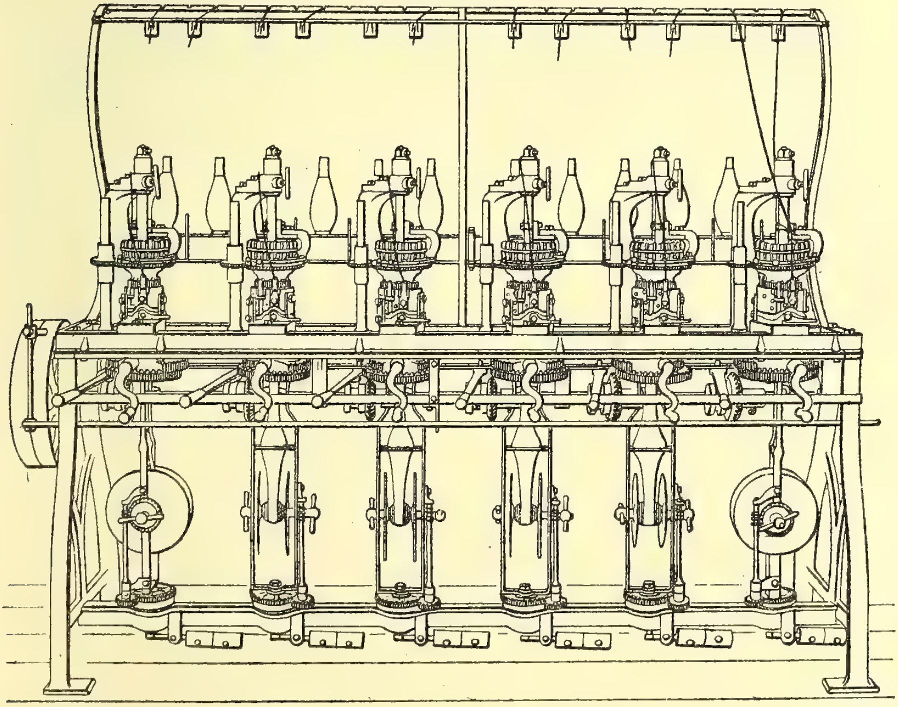

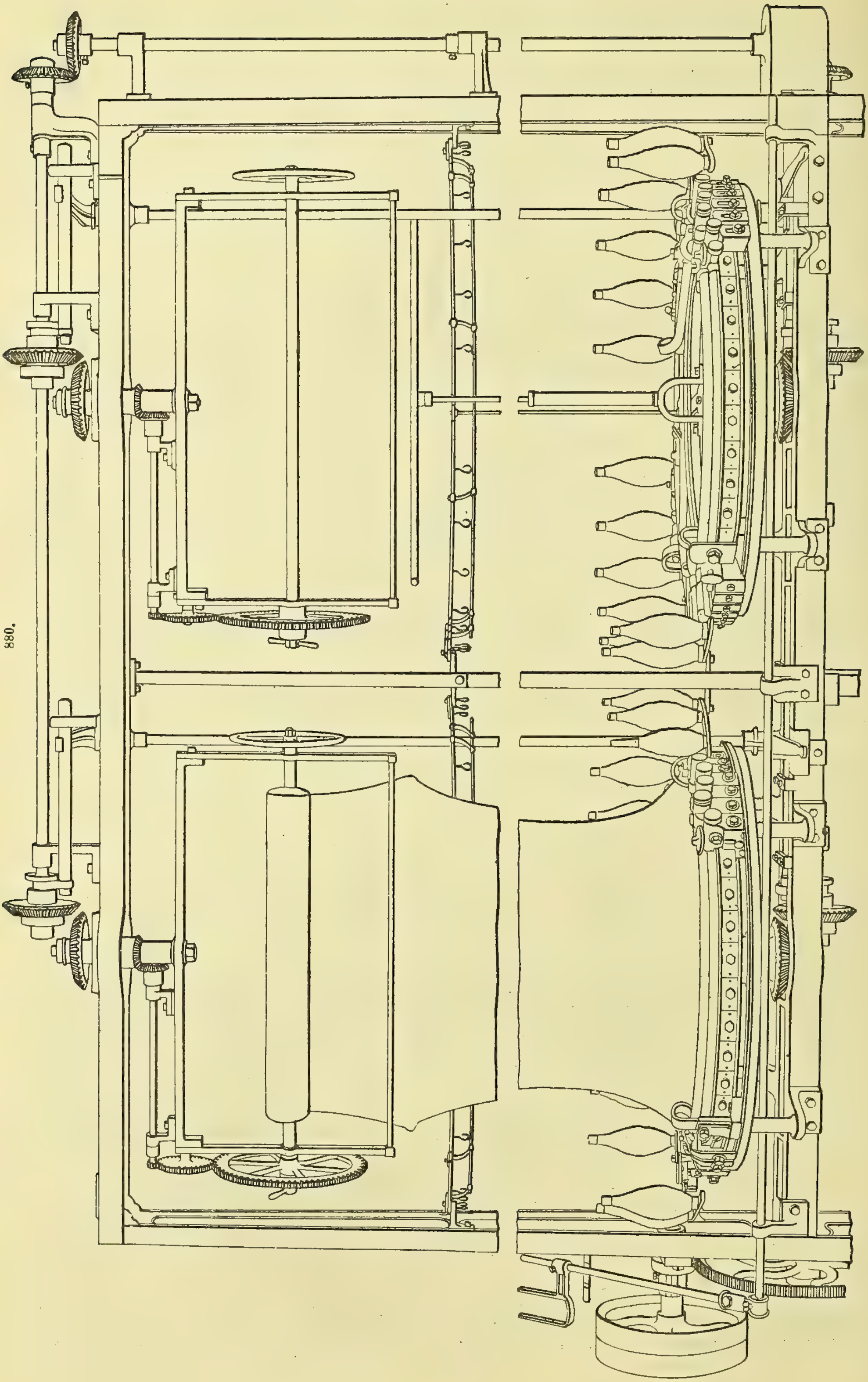

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threads to slip over the head of the needle, and upon the loops that are in the hooks, thus forming another course of the web. The needles being again elevated, the loops in the hooks slip down upon the shank of the needles, the latch falling back from the position shown in the illustration, in order to permit this action. The hooks, having received another thread, are again depressed, and the operation is repeated. This machine is also made for knitting cuffs, or tops, with welt and slack course, as in the rotary rib-top frame. It is self-acting in all parts, and is made in all gauges. A girl generally superintends it.

Of late, the demands of fashion have led to the adaptation of the knitting-machine to the production of wide-looped fabrics, composed of wool, and which may be finished as woollen cloths, or otherwise, so as to preserve on the front the characteristics of a knitted cloth. The advantage such a cloth possesses over an ordinary woven web is its greater elasticity, and equality of strength in each direction. The stockinette-machine, on which this class of fabric is produced, is illustrated in Fig. 880, which represents a 2-head machine, the heads being of 35 in. dia. A tubular cloth knit upon this frame would be 105 in. wide, but owing to shrinkage when taken from the machine, this would be reduced one-third, a shrinkage which applies to all machine-knit fabrics. When milled in the finishing processes, it is further reduced in width by 10–12 in. One person superintends a 2-head machine of this description, from which he produces 300 yd. of cloth in a week of 54 hours. Machines on the same principle, having four heads of less diameter, are used for making circular webs to cut up into pants and shirts. These also are superintended by one person. For other purposes, the heads are made in varying diameters, as may be desired.

The great capacity of production attained on the stockinette-machine, in making wide woollen fabrics, almost impels to the conclusion that, for many purposes, it may in the early future supersede the ordinary loom. Up to the present, very promising results have been attained, and the rapidity with which it is being introduced into the woollen districts of Yorkshire lends countenance to this view. It would appear also that considerable economy will be effected in the cost of production by this process, owing to several operations in the ordinary system of manufacture being rendered unnecessary.

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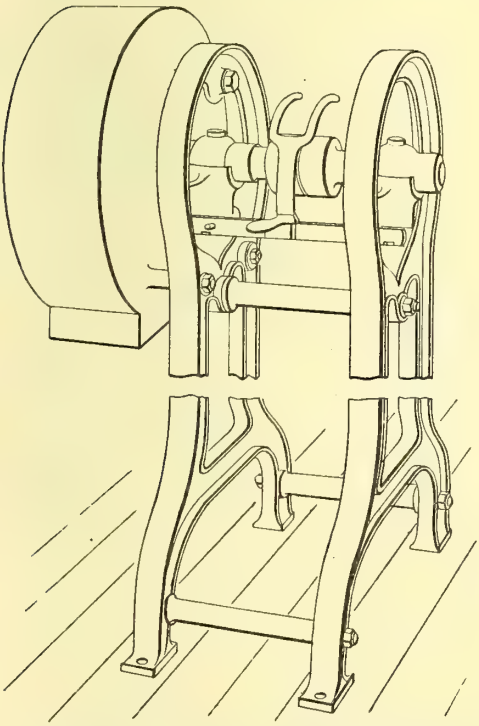

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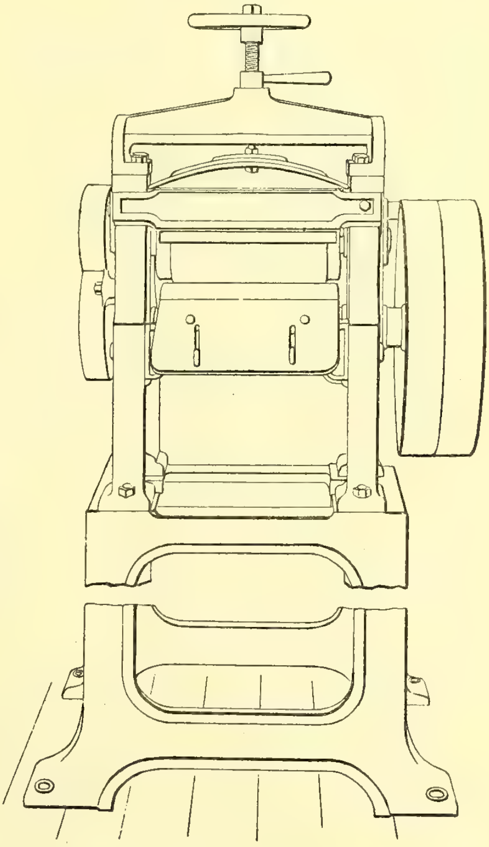

All circular hosiery-frames in working are liable, through knots or other irregularities in the yarn, to have their needles crossed or displaced, and thereby to "burr" or roughen the blades of the wheels. These imperfections are best removed, and the parts restored to order, by subjecting them to the action of the circular brushing-machine, represented in Fig. 881. Though perhaps not absolutely a necessary adjunct of a hosiery-factory, it is essential to secure a good quality of work, and a large production.

Hosiery manufacture, considering its magnitude, is distinguished by its simplicity. In rare instances only do those engaged therein spin the yarn they consume. The latter is generally ready for the hosiery winding-frame as it comes from the spinner, and being next supplied to the knitter, is fabricated into an article so perfect as to require but very little further treatment in the finishing processes.

The first in the series of finishing-machines, is the calendering-press, Fig. 882, used for rolling or calendering all circular hose, preparatory to cutting the feet. In this class of hose, a sufficient length is woven or knit in the frame in one piece to form a pair. These lengths are drawn upon a board, with the exception of about 1 in., which is left overhanging at the end. This part is presented to the calender-rollers, which, as they are rapidly revolving, seize it, and draw off the board the length of web; this, in its passage, is subjected to heavy pressure, and made to assume and retain the required form sufficiently long to undergo the next operation. As it emerges from the pressing-rollers, each length is received by an attendant girl, and laid in lots of a dozen each, in which quantities they are passed to the cutter.

Common hosiery, woven in the tubular form in double lengths, requires to be cut in a peculiar manner, in order to form the foot with comparative neatness and facility. The tube is first cut transversely half-way through, then longitudinally on each side for a distance of about 16–18 in., and the separation of the two portions is then effected by a transverse cut like the first. Each length then consists of equally-sized portions of hosiery web, about one-half of each part being tubular, and the remainder a longitudinal section of the same, flattened out. This cutting process is accurately and quickly performed on the machine shown in Fig. 883, which is so constructed as to cut with facility 100 doz. an hour.

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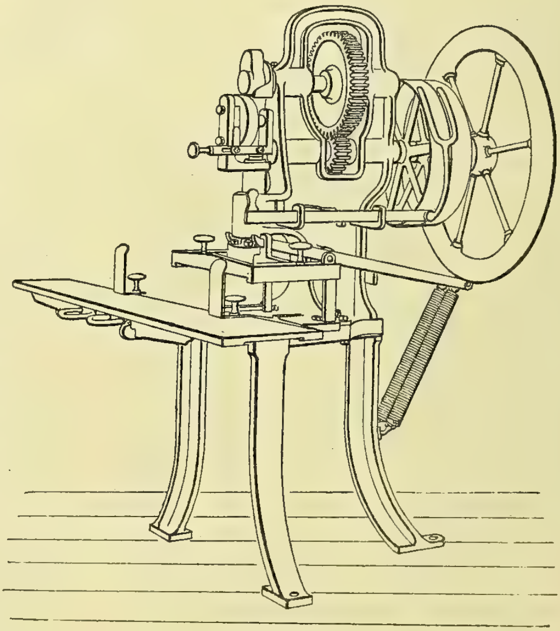

All frame hosiery, whether of the best or low qualities, requires more or less mending and finishing, by hand, sewing-machine, or looping-frame, by which the joining of the parts is effected more neatly than by the other ruder process. These finishers are usually women and girls, who are denominated "menders" and "seamers." By long practice, they become very expert and swift, and the various articles pass through their hands with surprising expedition.

After the menders and finishers have disposed of them, the last process previous to making up into dozens, or "boxing," in the case of fancy articles, is "hot pressing," which gives a certain degree of permanency to the form of the article.

The steam-heated press, Fig. 884, is the means by which this is accomplished. Its construction is exceedingly simple. Both the table and the top are cast with a series of passages through them into which the steam enters and circulates, and by which a great heat is obtained. Common tubular hose are drawn upon shaping-boards singly, and a dozen of these are put into the press together. A few moments' subjection to the heat and pressure is all that is necessary to give the desired shape, and while one set is undergoing treatment, another is being prepared. Fashioned goods, such as pants, shirts, hose, half-hose, &c., are treated in the same manner.

The commercial centres of the hosiery trade are Leicester and Nottingham, the former dealing chiefly in worsted goods, and the latter in cotton and merino articles, the last word being technically employed to indicate a mixture of cotton and wool. Each town is surrounded by a number of smaller places, in which much of the business of production is carried on, the articles being subsequently sent to the above centres respectively.

Cotton yarns are obtained from Lancashire, and chiefly from Ashton, Stayley Bridge, and

Bolton. Worsted yarns are mostly procured from Bradford and the neighbourhood, and merino or union yarns from Halifax and the localities around.

The Parliamentary Return for 1879, relating to the textile industries, gives the following figures concerning the number of manufacturing establishments and the people employed therein :—

Hosiery Factories of the United Kingdom.

England and Wales.	Number of Factories.	Number of Children working half-time.		Number of Males under 18 years working full time.	Number of Females above 13 years of age working full time.	Number of Males above 18 years of age.	Total number of persons employed.		
		Males.	Females				Males.	Females.	Total.
Middlesex, Surrey, and Kent	2	..	..	8	28	65	73	28	101
Leicester, Rutland, Lincoln, and Nottingham	165	145	222	756	6,990	4,486	5,387	7,212	12,599
Derby	8	2	..	88	603	378	468	603	1,071
Total for England and Wales	175	147	222	852	7,621	4,929	5,928	7,843	13,771
Total for Scotland ..	10	16	14	59	442	571	646	456	1,102
„ „ Ireland ..	1	7	..	9	10	93	109	10	119
Total for the United Kingdom	186	170	236	920	8,073	5,593	6,683	8,309	14,992

The Returns from which these figures are taken, being only those of the number of factories authorized to be inspected under the Factories and Workshops Acts, the persons still engaged in the domestic branch of the industry did not come within the cognizance of the enumerators, otherwise a considerable addition would have been made to these totals. A more important omission is the failure to give a census of the machinery employed in the various sections, or at least in the three broad divisions of worsted, cotton, and merino (union), productions.

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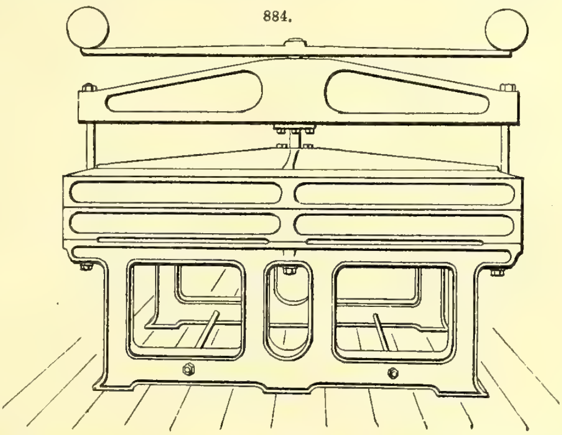

That the above enumeration conveys a very inadequate idea of the importance of the hosiery trade, may be judged from the fact that, in the hosiery business of Nottingham alone, there were at work in 1865, 11,000 narrow hand machines, employing domestically 7500 men and 3500 women and youths, at wages ranging from 6*s.* to 26*s.* a week, averaging 10*s.* 6*d.*; also 4250 wide hand machines, domestically employing 4250 men earning 10*s.*–30*s.*, and averaging 15*s.* a week. These 15,250 hand frames were scattered over eighty parishes in the county of Nottingham. These two classes of Nottinghamshire hand machines give employment to about 20,000 women and girls as winders and seamers, earning about 4*s.* each on an average. There were also about 1000 wide power rotary-frames employing 700 men, at 20*s.*–32*s.* a week; and about 1600 girls and women seamers and winders, whose average earnings were 5*s.* weekly. There were in addition to these, 1200 sets of circular round power frames improved, employing 500 men and 500 youths, at 12*s.*–25*s.* weekly; and 1000 women at 12*s.*–20*s.* weekly. The winders, cutters, menders, and others attached to these were about 11,000 women and girls, averaging 7*s.*–12*s.* weekly. On about 400 warp machines, making hosiery by power, 400 men were engaged at 14*s.*–35*s.* a week, and 200 youths at 12*s.*–20*s.*; besides 400 men warpers earning about 25*s.*, and 2000 women and girls stitching, &c., at an average of 8*s.* a week. In bleaching, dyeing, and as porters, 2000 men were probably employed, at 20*s.*–35*s.*; and 5000 menders, folders, &c., were occupied in the warehouses at 8*s.*–12*s.* weekly. To these should be added the staffs of warehousemen and clerks employed in the 80 establishments for finishing, and sale of goods, in Nottingham. These, all told, would make a total of fully 60,000 individuals.

The number of hands employed in the entire English hosiery trade in 1866 was computed to be as follows:—42,000 working narrow frames, 8000 at wide ones, and about 100,000 menders, winders, seamers, cutters, finishers, and makers-up, who are chiefly women and children—a total of 150,000 persons.

The value of the production in 1851 was estimated at 3,600,000*l.*; in 1862, at 6,480,000*l.*, and in 1865, at 7,795,000*l.*, which last advance was chiefly due to an increase in the price of the raw material. Afterwards there was a decline from this amount, but the subsequent growth of the trade will probably have carried it by this time to a point near 10,000,000*l.* per annum.

The hosiery industry has taken firm root in several foreign states, notably in France, and Saxony, and less firmly as yet in Russia, Austria, Spain, and Italy. In the United States of America, it has become comparatively flourishing, under the commercial policy adopted in that country. Several less important communities have also recently endeavoured to introduce the industry. When all chances of rivalry, however, are fully discounted, it is conclusively evident that there are no insurmountable obstacles to a still further great development of the English branch of the trade.

R. M.

LACE (Fr., *Dentelle*; Ger., *Spitze*).

Lace-making is the most artistic of the textile industries, and its productions have always been regarded as an especial appanage of the wealthy and luxurious classes of society. Lace is the last outcome of the development of those arts of ornamentation whose chief instrument is the needle: embroidery, tapestry, appliqué, &c., in which women have been skilled from time immemorial. Though tracing its evolution through the most civilized ancient peoples, the art itself is comparatively modern, the earliest discovered references to lace occurring during the 15th century. It is not improbable that society owes it to the system of monastic seclusion accompanying the Catholicism of the Middle Ages, when the gentler sex devoted much time to the cultivation of needlework and similar arts. There is little doubt that knitting also had its origin in the cloisters, and the transition from that art to lace-making would be comparatively short and easy. After its development, lace-making spread into the outer world, and became the favourite pursuit of ladies in the higher social circles of different nations, superseding the older feminine arts of needlework, embroidery, and tapestry. Female dependents doubtless also learnt the art, and taught it to the members of their own families, thus laying the foundation of those industries which, favoured by local circumstances, have grown into national importance. In the course of time, these different centres have developed special characteristics, by which the productions of one place can be distinguished from those of another.

Lace-making may be divided into two great branches; manual, or the system of making by hand; and mechanical, or the method of making by machine. The former is the original and most widely spread system; the latter is a development of the mechanical skill of the 19th century, and has already attained great perfection. By cheapening the production and reducing the price, it has brought the elegant productions of the art within the reach of nearly all classes; and while ministering to the refinement of public taste, has given rise to a new industry, employing many thousands of people, whose welfare cannot be an object of indifference.

The manual system of lace-making, which is still extensively followed in Belgium, France, and, to some extent, in this country, will naturally first claim attention, on account of its greater magnitude, its wider extent, and the much higher estimation in which its products are held, over those produced by mechanical appliances. Hand-made lace is generally known as "real" lace, whilst that produced by machine is regarded as a counterfeit, and called "imitation." In the best qualities of the former, only the finest flaxen thread is used; whilst in the latter, very fine cotton thread is substituted.

The materials from which lace is fabricated are various, and include flax, silk, cotton, gold, silver, and threads from several other fibres. These are used in various degrees of fineness, according to the character of the work required. Generally, however, the thread is very fine, and of good quality, when compared with that employed for other purposes.

Hand-made Lace.—Lace proper, or hand-made lace, usually consists of two parts: a ground of plain network, composed of honey-combed or six-sided meshes, formed in different ways, according to the variety of the article being produced. On this ground, the second part, the pattern, is worked. Sometimes the ground is dispensed with, and the parts of the pattern are connected by threads irregularly attached, overcast with the button-hole stitch, and ornamented according to the style of the design. In some kinds, there is no ground at all, the objects represented joining each other. In the varieties known as Mechlin, Valenciennes, and Buckingham laces, and in several others, the pattern or "gimp" is made with the ground. Brussels and Honiton laces are composed differently, the gimp being worked separately, and then sewn on the ground. Around the edge of the pattern, there is generally a little raised cord, called "cordonnet." The upper edge of lace is often composed of very small loops, which constitute what is called a "pearl" edge; whilst the lower or "footing" is a narrow lace, by means of which the work is attached to the material whereon it is to be worn. The fabric as a whole is exceedingly intricate. To the uninitiated, the ingenious entanglement of threads is an insoluble mystery, and still more so is the fact that out of this tangle are produced the most beautiful designs: geometric figures, leaves, flowers, and creations of the fancy of the most elaborate kind.

Hand-made lace may be broadly divided into two classes: (1) "point," or needle-made kinds, of which, some of the best as well as the earliest are the ancient laces of Italy, Spain, and Portugal, and for which Alençon, in France, has more recently become noted; (2) "pillow-lace," which, as its name indicates, is made by weaving, twisting and plaiting together upon the "lace-cushion" a number of threads supplied from bobbins.

Point-lace, as previously indicated, probably originated in the convent, and its invention is usually claimed for Italy. During the 16th century, it became widely known, and was in almost general use, being applied to a great number of purposes. The lace of this period was chiefly of geometric design: combinations of squares, circles, and other figures in repetition.

It was probably not more than ½–¾ of a century after the invention of point-lace, that the art of pillow-lace making was invented—the credit of this is generally assigned to the Netherlands. It was subsequently introduced into Germany by Barbara Etterlein, a lady of Nuremberg parentage, who went to reside in the Hartz mountains, where she married a rich master miner, Christopher Uttmann, of Annaberg. In the mining districts of the Hartz, it was customary for the workmen to wear their hair confined in nets, which were woven by the females. Barbara, observing this, introduced the pillow, and taught them to make a plain lace ground, as an improvement upon the articles they were fabricating. This art, it is alleged, she had acquired from a Brabant refugee. Pillow-lace making became so popular, that Frau Uttmann set up a workshop at Annaberg, where she taught the art to many, and made lace of various patterns. After her death, on Jan. 14th, 1575, an inscription placed upon her grave claimed for her the invention of pillow-lace. Whether this claim is justly grounded or not, cannot be decided here, but the fact is certain that, from Annaberg as a centre, the art spread over Germany, and thence into surrounding countries.

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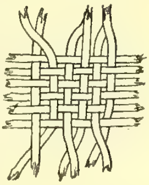

Point- or needle-lace is usually the production of one thread, upon which loops are made and joined to each other by intersections, in such a manner as to form patterns. In pillow-lace making, on the contrary, more threads are used, the number sometimes reaching 400–500, and in exceptional cases, 1500. It will be obvious that the management of such a number of threads is a more complicated matter than that of dealing with one, and that the fabrication of the beautiful patterns into which they are formed needs a more complete instrument than the simple needle. A series of pins, with a cushion in which to arrange them, were found the most pliable instruments, and to afford the greatest facility for the interweaving or twining of the threads. Pillow-lace is made by simply twisting, plaiting, and weaving together a number of threads, in such a manner as to form them into any desired pattern. The process is to first draw the pattern upon parchment, and make holes in the outline of the design, wherein to insert pins, around which the threads are twisted so as to form meshes. Fine and coarse threads can be combined, and two or more can be worked together for a time and then separated. With the progress of the work, the pins are moved to new positions. In making figured lace, it is necessary that the threads should be so arranged as to allow of their being passed around each other as often as required. In pillow-laces, the pattern is chiefly made by weaving the threads so as to form what may be termed a portion of plain cloth, Fig. 885; the ground or mesh by plaiting, Fig 887; and in other descriptions, by intertwining the threads, as in Fig. 886. The ground of Brussels and Honiton lace is formed as in Fig. 887, which represents a 4-thread ground.

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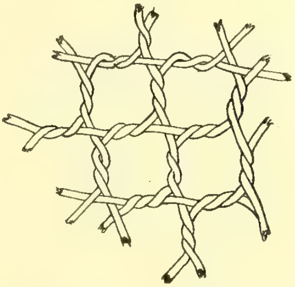

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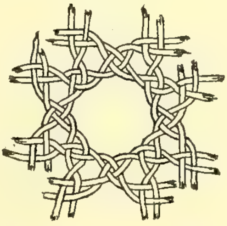


England owes its pillow-lace making industry to refugees from the Netherlands, who fled from the persecutions of the Duke of Alva, and sought an asylum in this country in the 17th century. The industry took root in the shires of Bedford, Buckingham, Oxford, Northampton, and Devon; but the two centres which have become most distinguished and successful, are the districts embracing Honiton, in Devonshire, and the county of Buckingham. In the former, the manufacture of lace is carried on over a district along the coast about 30 miles in length by about 12 in breadth, which includes Seaton, Beer, Branscombe, Sidmouth, Exmouth, and the vale of Honiton.

At one time, as many as 10,000 people have been employed in the lace industry in this district.

Honiton lace is made by placing a perforated pattern upon a pillow, and employing pins, bobbins, and spindles to twist and interweave the threads in such a manner as may be required. In the early stages of its existence, the Devonshire industry was confined to the production of sprigs and borders, but during the past half-century, such progress has been made as to result in the manufacture of articles of great value, displaying taste and beauty of design, and delicacy of execution. These comprise flounces, shawls, bridal veils, scarfs, handkerchiefs, &c., some of which range in value from 10*l.* to 300*l.*

The Devonshire lace resembles Brussels in the mode of manufacture: but within recent years the style has changed, and the ground has been replaced by the modern guipure. The "old ground," as it is now called, was beautifully fine and regular, and made of flaxen thread procured at Antwerp, where its market price in 1790 was 70*l.* the lb. During the wars at the close of last century and the beginning of this, when it was difficult to obtain the yarn, smugglers who succeeded in getting it into the country obtained as much as 100*l.* for 1 lb., and the lace-makers received as much as 18*s.* a yd. for making the ground of border lace not 2 in. wide. It was, however, with the sprigs and borders that Honiton achieved its fame. They are made separately on the pillow, and the former, in the early days of the industry, were worked in, but afterwards applied or sewn on the ground, which is now usually a machine-made net.

Beds, Bucks, and Northampton laces once stood very high in public estimation, being greatly admired for the clearness and beauty of their point grounds; but owing to fluctuations of demand, the industry in these districts has greatly declined. Formerly the class of laces chiefly made were narrow ones used in trimming infants' caps, robes, &c., but the fashion having changed in some respects, and machine-made goods superseding them, these have been abandoned, and the workers now produce the descriptions known as Cluny and Maltese.

There are several other descriptions of hand-made lace produced in the British Islands. Of these, the principal are British point, made in the neighbourhood of London, which is of good quality, regarded as an imitation of Brussels. Limerick lace has achieved a wide reputation, and vast quantities have been produced. Lace-making was introduced into Ireland during the last century, but, as an industry, made very little head-way until after machinery was adopted for the spinning of flax, which threw a large portion of the female population out of employment. Along with embroidery, lace-making began to make progress, though not to the same extent as the former. After the famine in 1846, training-schools were established in many parts, and lace was made with considerable success. Amongst the descriptions produced were point, guipure, imitations of ancient point, Ypres Valenciennes, tatting, and other kinds which secured public favour.

English hand lace-making has, however, always been a secondary industry compared with that of other countries. Amongst the states on the Continent, France occupies the premier place. Thirty years ago, the number of females employed in the hand-made lace industry of that country was estimated at over 200,000, ranging in age from 7 years to an advanced time of life. It is not probable that this number is diminished, or if so, it can only be to a small extent. The money earned by each worker ranges from 6*d.* to 1*s.* for a day's work of 10 hours, varying according to the demand there is for the article.

Hand-spun linen thread, cotton, wool, silk, and gold and silver thread mixed with silk, are the materials employed. About ½ century ago, all the white lace was made from hand-spun linen thread; but cotton yarns, ranging in Nos. from 120's to 320's, are now almost solely used.

The hand manufacture of lace as an industry is very widely spread in France, extending over many departments. Each district is remarkable for the possession of some peculiarity of style, which is well known in the chief markets, and easily recognized by experts amongst dealers. The most important centres of production are Caen and Bayeux, Chantilly and district, Lille, Arras, Mirecourt, Du Pay, Bailleul, and Alençon.

Caen and Bayeux, in the department of Calvados, are celebrated as the chief centres of the manufacture of silk-lace in length and piece-goods: veils, scarfs, mantles, robes, shawls, &c. The first silk blonde was made at Caen, and given that name from the fact that it was made of undyed silk. This article rose high in public favour, but subsequently the demand fell away to very small dimensions, and, for a long time past, the chief product has been black lace. The manufactures of these districts are widely celebrated, mainly on account of the skill of the workpeople, of whom there are 30,000–40,000 employed. The women are remarkably quick at the work, and, by means of a stitch called *rucroe*, join different parts together in such a manner as to be invisible to the closest scrutiny. By the use of this stitch, they are enabled to divide a task amongst a number of workers, whereby it can be completed in a much less time than if performed by one woman.

Chantilly lace possesses most of the characteristics of the preceding, but excels it in fineness of texture, beauty of design, and perfection of workmanship. It takes its name from the birthplace of the manufacture, but its fabrication has long since spread into the neighbouring districts. The manufacture is not nearly so extensive as that of Caen and Bayeux, and is confined to the production of articles designed to satisfy the taste of the most wealthy and luxurious classes of society.

The lace industry of Lille is said to be the oldest in France, but it has long been in a declining condition. *Fond clair*, or clear foundation thread-lace, was the best-known article produced here. Lille possesses several other industries which afford better-paid employment for the female portion of the population, the consequence being that lace-making has greatly declined. That of Arras is in a similar state to the above, and what remains of its manufacture is greatly wanting in novelty and good finish, but is sold at a low price, and hence meets with a demand sufficient to absorb what is made. Mirecourt, in the Vosges, makes a lace similar to that of Lille, but displays more enterprise and taste in the introduction of new designs than either that town or Arras. This place is also noted for the production of "guipure," similar to the lace of that name produced at Honiton.

Puy, in the Haute-Loire, is a great centre of the lace industry; in the town and district, there are 30,000–40,000 people employed. A great quantity of the lace produced is coarse, of low texture, and cheap in price. Other varieties are made in thread, silk, and wool, amongst which are included "point," "point de Chacey," and "point de Valenciennes." Blonde, black, and white lace, and many other descriptions in every colour, especially worsted laces, are also produced.

Bailleul is the chief place in France for the manufacture of Valenciennes, its production greatly resembling that of Bruges in Belgium. The lace made here is remarkably white, and is sold at a cheap rate. It is rather thick as compared with other descriptions.

The celebrated "point d'Alençon" is a needle-made lace of the highest quality. Its manufacture was introduced into France from Italy, in 1660, by the minister Colbert, who obtained workmen from Venice and Genoa. These at first made the lace to which they had been accustomed, called "point de Venise," and afterwards "point de France." Subsequently variations sprang up, and the manufacture then became known as "point de Alençon," from the town in which it was made. This lace is now very different from most other point laces, which need only one worker to complete the richest article, Alençon, on the contrary, requiring 12–16 different workers to complete the smallest piece of the simplest pattern. Amongst these, may be mentioned the *traceuses* and the *reseleuses*, who make the net or ground; the *bourreuses*, who do the heavy portions or patterns of the lace; the *modeuses*, who make the open work; and the *brodeuses*, who fabricate the border destined to surround and support the patterns. This lace is now the only kind made with pure handspun linen thread, the price of which ranges from 100*l.* to 120*l.* a lb. The women employed in making Alençon lace are extremely skilful, and the article is the strongest, finest, and richest of all laces, and commands the highest price.

The lace industry of France is of national importance. It employs a large proportion of the population, and a great amount of capital. It is essentially a domestic industry; all the females employed work in their own homes, under the immediate supervision of their elders, who are their chief instructors.

Next to France, Belgium possesses the greatest repute for hand-made lace. The chief centres of its lace industry are Brussels, Antwerp, Malines, Ypres, Bruges, Ghent, Menin, Courtrai, and Alost, with their surrounding villages. In these districts, a population of probably over 100,000 persons is employed in the fabrication of lace.

Brussels lace is of the highest quality, and consists of two kinds, point and pillow, the former being made entirely by the needle, and the latter on the pillow. The finest descriptions, which realize the highest prices, are made of fine flaxen thread. In others of great excellence, cotton yarns are used. In former times, these laces were only made upon "real" ground, but after the manufacture of net by machinery had been perfected in England, this was to a large extent substituted, and has had the effect of greatly reducing the cost. The "real" or hand-made ground was wrought on the pillow in narrow strips of 1–3 in. wide, which were then joined so perfectly as to render the line of attachment quite invisible. The best hand-made lace was so costly as to find customers only within the circles of royalty or families of the greatest wealth. Trimming laces 3–4 in. wide ranged in price from four to ten guineas a yd., whilst veils of the same qualities sold for 20–150 guineas. The introduction of the machine-made ground, however, so reduced these prices as to greatly enlarge the circle of consumers, and since that time they have been in extensive use by persons in the higher and wealthier circles of society. This change greatly stimulated the Belgian industry.

This modified or combined hand- and machine-made lace is known as the "application of Brussels," and, in its perfect resemblance to the real article, is calculated to deceive the most skilful and expert judges. The flowers or designs are made by hand, and then sewed upon the net. Brussels "plait-net" is extensively worn upon the Continent, but "point" has generally been in more favour in England.

The fabrication of Brussels lace is divided amongst a considerable numbers of workers, one class making the flowers in plait, another those in point, a third "real" ground, a fourth the ground in the flowers; a fifth fasten or combine the different parts, whilst a sixth attach the foregoing to the net ground. In some particular descriptions, there are two or three additional classes of workers. The quality of Brussels lace is only surpassed by the point d'Alençon made in the north of France.

The descriptions of lace known as Mechlin are made at Malines and Antwerp, and their vicinities. These laces are made on the pillow in one piece, and are of remarkably light and fine texture. They are peculiar in having a plait thread surrounding the designs and flowers, and forming their outline, which give them the appearance of embroidery.

Valenciennes constitute another variety, which rank amongst the most highly esteemed laces made in Belgium. These are chiefly produced in Ypres, Menin, Courtrai, Bruges, Alost, Ghent, and the villages surrounding these towns. This lace is also a pillow-lace, yet the production of each town displays such peculiarities that they can be easily distinguished by experts. The first-named town began the manufacture in or about 1656, but for a long time, it did not make much progress. Since the commencement of the present century, it has extended greatly, and, a few years ago, was estimated to employ in the town and environs fully 20,000 persons. The productions are exported to England, France, Germany, and the United States. Ghent makes very high-class articles, chiefly in narrow and medium widths, and employs 10,000–15,000 workpeople. The laces of Bruges are of a medium quality, and lower in price than those of Ghent; but they are of an eminently useful character, being especially adapted for trimmings. Alost makes some good laces of similar designs, but not equal in quality to those of Ypres. Grammont laces are white thread, and black point trimming laces of good quality.

In all hand-lace making districts, the industry is mainly of a domestic nature, hence there is not that close and continuous devotion to the labour that exists in other occupations more highly organized, and conducted on the factory system. In most cases, the females have charge of household duties, and take up their lacework in the intervals of domestic occupation. This can be done without detriment if they are careful not to injure their hands. Their earnings are very small. Where it is more persistently engaged in, the remuneration is better; but in the best circumstances, it is an ill-paid industry, requiring a long apprenticeship and close devotion to attain proficiency. It frequently takes several months, and often a year, to complete a short length of 3 yd.; and in these cases, the employer is compelled to make advances to the lace-maker, besides supplying the costly yarn for the manufacture. Ten years ago, the number of persons following the occupation in Valenciennes, was reduced to three, who were earning only 1*fr.* 30*c.*–1*fr.* 50*c.* for 12 hours' work. In the Belgian towns where the lace of this name is made, the wages are rather better, though not to an important extent. The price of a lace-maker's cushion is 8–10*fr.*, and the patterns cost 75*c.*–1*fr.*; the worker provides her pins and spindles, which number often 1500 pins and 250–500 spindles employed in the production of one piece of Valenciennes lace only 3 yd. in length.

Lace-making in Italy has become almost extinct, the method of making some of the most prized descriptions having been lost. One sort formerly of high repute was known as Burano lace, and about 12 years ago, an attempt, attended with some degree of success, was made to revive the industry. An old woman was found who was stated to be the last of her craft who still remembered the method of making this lace, and under the auspices of Princess Giovanelli and Countess Marcello, she was engaged to instruct a number of girls in the almost forgotten art. The first specimens produced sold very freely. The cost of the fabric was about 100*fr.* a metre of 12 *cm.* wide, and this was regarded amongst connoisseurs as beneath its proper value. The time required to produce this length is 150 days of 5 hours each, for which the workwoman receives 50*c.* per diem. Dr. Fambri, an Italian deputy, made the following estimate of the labour and cost involved in making one metre of this lace, of a kind and quality never surpassed in ancient times: (1) 3 months' wages of one hand for the net work; (2) one month's wages of one hand for the pattern or flowers; (3) one month's wages for the ornamental border. He also suggested that the industry should be carefully cherished and developed, not only in order to preserve the secret of the art, but also as offering an employment capable of affording maintenance to thousands of people on a merely nominal capital.

Machine Lace Manufacture.—The era of mechanical invention, which commenced in the textile trades in the middle of last century, has had a vast influence on every industry. Naturally, however, this influence has been most conspicuously exerted in the spheres in which it first made itself apparent. This will be admitted, when the fact is reflected on that the cotton trade, as it exists to-day, has entirely sprung from its development, that the woollen industry has been completely revolutionized, and similarly the manufacture of flax. The silk trade has perhaps hardly undergone quite so much change, but this is more owing to the nature of the fibre dealt with, than to the incapacity of inventors to meet its requirements. But in no section of the textile industries, have the latter been more successful than in the one under consideration—the manufacture of lace.

The wide area in this and other countries over which lace-making was spread, the slowness of its processes, and the high prices obtained for the product, soon attracted the attention of men anxious to emulate the success of Strutt, Hargreaves, Arkwright, and other pioneer inventors in the cotton trade. But it was some time before the vague notions entertained began to assume definite shape. The stocking-machine of Lee, as improved by Strutt, was the instrument generally regarded as most likely to yield satisfactory returns for careful study and development. Strutt's success led to the hope that the more intricate patterns of the hand knitter might be successfully imitated mechanically, and amongst these were the various lace patterns that had been introduced into hand-made hosiery. This anticipation, as the result has shown, was not baseless, for the machine-lace industry is entirely a development arising out of the Calverley curate's invention.

The addition of tickler-points to Strutt's improved machine, by which the loop formed upon one needle was removed to the next adjacent one on either side, was the first step in this direction. By the arrangement adopted, the loops on the needles were transferred to the tickler-points, and whilst they were upon these, the tickler-bar was "shogged" or moved in a lateral direction, by which the loops were carried to and placed upon the required needles. This ingenious arrangement was the invention of a stocking-maker named Butterworth, living near Mansfield. Butterworth had to entrust the details of his plan to a smith named Betts, whom he employed to make the necessary parts; but conjointly they were unable to proceed to secure it by a patent, or even to perfect the plan, so a third person was induced to join them, a man called Shaw. Betts appears to have been an unscrupulous man: he eliminated the inventor from the party, and introduced a more able capitalist than Shaw in John Morris, a Nottingham hosier. Betts, Shaw, and Morris went to London and secured a patent, in the names of John and Thomas Morris, and John and William Betts, leaving out of the instrument all mention of both the inventor and Shaw. In the absence of the latter, Betts transferred the whole property of the invention to Morris, and thus defrauded both of his former partners of their share. This particular invention is interesting, because the specification states that the invention was "for making by a machine, to be fixed to a stocking-frame, eyelet-holes or *net-work.*"

Shaw, feeling disappointed and injured, subsequently went upon the Continent, where he saw a better method of making open work than any with which he was acquainted, and which he introduced into England on his return. In the meantime, the machine, which had become Morris' patent, was further improved by Else, who dispensed with one eye in the form, and with the ticklers. This was used in England for some time, but subsequently was superseded and almost forgotten. In the days when it was penal to export machinery, it was smuggled over to France, and the Convention liberally rewarded the person who succeeded in getting it across the Channel. Improved and developed, it is the machine which at Lyons is used to this day for the production of single and double silk net.

Morris, encouraged by his previous successes, laboured in the further development of the machine, and, in 1781, patented another improvement, whereby the sinker-loop was put across two needles, and the feat of making point-net was accomplished. These inventions in combination formed a remarkable advance in the progress from the hosiery-frame to the lace-machine. This was, however, soon surpassed by an invention perfected by Else and an associate, who discarded the tuck-presser, substituting and regulating the action of the tickler on a sliding needle-bar, and imparting to the latter a "shogging" or lateral motion to remove the stitch by means of the tickler alone. This nearly doubled the productiveness of the machine, but Morris, who still held the patent right of Butterworth's invention, sued Else for infringement.

Thomas Taylor, of Nottingham, invented a machine for making figured lace in 1769, which may be regarded as the basis of the idea so successfully developed afterwards by Jacquard. In Taylor's invention, a slide-lever tickler was used to every needle, and those which were desired to work were pushed into action by means of an organ-barrel, carrying pins upon its periphery, arranged according to the pattern. These acted upon pins at the ends of the tickler-slides which were required, leaving those not wanted to remain at rest. Any stitch in the row could thus be moved at pleasure and any pattern be produced.

Hammond, an ingenious workman, improved Taylor's machine in different points, and made upon the modification several varieties of looped fabrics to which he improperly and incorrectly gave the name of Valenciennes lace. About the same time, 1768, Crane, an inventor, of Edmonton, added a warp-frame to the stocking-machine, which subsequently formed the germ of the warp lace-machine. Some unknown person effected a great advance by devising a plan whereby the stitches were removed so as to leave large interstices, which received the name of "bullet holes," and these, being surrounded with needlework, formed the basis of the subsequent large business of lace-running, in which as many as 150,000 females are stated to have been employed.

Improvements followed each other in rapid succession, but they were chiefly in small details. About 1777, Holmes invented a plan of making what was called "two-plain" net, and Frost, in the same year, brought out the square net, and subsequently flowered net. A great advance was effected about this time by the invention of what was called the point-net machine, which is attributed to a journeyman stocking-maker named Flint, of Nottingham. Either pressed by poverty, or not appreciating the value of his improvement, he sold his invention to a neighbouring frame-smith, who effected further improvements, and disposed of the plan to Morris. This machine further improved by the application to it of an invention of John Rodgers, of Mansfield, laid the foundation of the prosperity of the lace trade of Nottingham. By it, was obtained a mesh which was perfect in shape, and fast in its texture. The fabric produced from it was subsequently embroidered in all sorts of designs, this process finding employment for many thousands of people in Nottingham and neighbourhood. The articles produced consisted of edgings, insertions, borderings, flouncings, veils, scarves, and other articles required by the fashion of the day. The widths varied from 1 to 30 in. Owing to changes in fashion, and deterioration of the quality, the lace made on this frame rapidly declined in quantity after 1810, and was nearly extinct in 1815.

The inventions described up to this point for lace-making purposes were all modifications of or additions to the stocking-frame. A distinct departure in the principle and style of the machine, and from which modern lace machinery has been developed, took place in 1775 by the invention of the hosiery warp-machine by Crane, a workman of Edmonton. In this invention, the warp of the ordinary loom was introduced, a thread was given to every needle, and the looped stitches of the stocking-frame were formed upon each. This frame was successively improved by other inventors, and so much increased in width, that its productions entered the market in rivalry with ordinary woven fabrics, with which they successfully competed for clothing purposes. It is singular that, in the present day, the stockinette-machine of Nottingham should threaten to become the successful rival of Yorkshire and West of England cloth-looms, yet such is the case.

The allotment of a thread to every needle greatly increased the capability of varying the mesh upon this machine over the hosiery-frame, though twenty years elapsed before the advantage was discovered or practical use made of it. About that time, attempts attended with considerable success were made to get open work from it with lace effects. These products were highly appreciated, and gave a great stimulus to further invention, by which the capacity of the machine was still more enlarged, and manufacturers were enabled to produce from it the finest silk-net lace, silk blonds and edgings, tattings, pearls, antimacassars, and doyleys, of all qualities and designs, which soon became and still remain articles of great consumption in the home and foreign markets.

The next improvement, and which greatly assisted in giving a distinct character to the lace-machine, was accomplished by William Dawson, a framework-knitter, of Leicester. By the device of a wheel irregularly notched on its edge, and which in its revolution operates upon horizontal bolts or bars, retained in position by springs on their edges, it effects such a displacement of the threads by this lateral movement, that a figure is wrought in the fabric according to the required design. These wheels are still known by the name of the inventor, who acquired considerable means by his invention, but squandered his wealth almost as fast as it was made, and, disappointed at not getting a renewal of his patent, died by his own hand.

The organ-barrel was the first embodiment of an attempt to obtain variegated productions in lace fabrics; this was followed and improved upon by Dawson's wheels, and finally perfected in the jacquard attachment, and the varied forms which the latter, in the hands of succeeding inventors, has assumed.

After the application of Dawson's wheels to the lace-frame in 1807, improvements followed one another in rapid succession. These can only be briefly enumerated. In the last-named year, the spotting-bar and wheels were invented; two years later, two-course silk-net was produced; and in 1811, dividing-bars were invented by Daycock and Morrison, which enabled them to make silk blonde. In 1816, warp-pearling was introduced by Fowkes and Kirkman. A new net called "mock-twist" next followed; and in 1822, warp-tattings were invented by Copestake and Read. In 1824, Hardy succeeded in spotting and figuring the above-mentioned mock-twist. Between 1830–5, there was a great demand for the productions of the warp-machine, which had attained the front rank of fashion, and won the favour of the Queen.

A most important improvement was made in 1839, when Draper successfully applied the jacquard machine to the warp lace-frame, by which its capacity was wonderfully extended, and articles of elaborate design, such as shawls, scarves, falls, and laces, were easily produced. Many other kinds of fabric besides lace were also made upon the warp-frame, such as elastic woollen cloth, hatbands, glove-cloth, piece velvet, and velvet pile ornamented lace. Herbert, of Nottingham, an ingenious man, by successive improvements, made tattings, cords, and braidings. Others followed who made taffeta, single and double looped. The warp lace-machine has been a source of great wealth to Nottingham and surrounding district, and has laid the foundation of many considerable fortunes amongst those who were best acquainted with its capacity, and knew how to utilize its advantages.

But the most important invention connected with the mechanical production of lace, judging from both its principles and results, was the bobbin-net machine of John Heathcoat. All others had been modifications of the hosiery-machine, making looped fabrics. Much ingenuity, skill, and money were expended by different schemers to produce, by mechanical appliances, a perfect imitation of pillow-lace. John Heathcoat was a man of rare mechanical genius, and, having formed the conception of achieving this result, bent the whole of his energy and skill to its accomplishment.

In some pillow-lace, one set of threads extend in a wave-like line longitudinally through the fabric, like the warp threads of a plain fabric; the other set take a diagonal course right and left, and are twisted round the first set, by which means hexagonal meshes are formed. All inventors previous to Heathcoat had been foiled in the attempt to accomplish the diagonal traverse of the threads. He achieved this by a plan patented in 1808, in which the bobbins were made to traverse the warp from side to side, twisting around the warp threads in their passage, and forming an exact and perfect imitation of the net ground of pillow-lace. The machine on which this was accomplished was of limited capacity, making lace no wider than could be produced on the cushion, while a great desideratum was the production of wide laces that should obviate the necessity of joining the narrow strips together. Heathcoat, discovering this, laid his first effort aside, and nine months after, patented a second, which quite revolutionized the trade. Speaking of this attempt at a subsequent period, he says, "The value of lace is so much enhanced by its being made of greater width, that I was determined to make it even a yard wide. At this time (after his first success), I had arrived at the important point that having actually made lace as above described, I had satisfied myself that my principles were sound and well based. But I now clearly found out that, while half the threads must be active, the other half might be passive, and I therefore put the latter on a beam. Having thus fixed the warp to accomplish my wish for making wider lace, I tried to bring the threads to twist in a narrower compass. I first tried a machine with the bobbins spread out; then I tried the flat bobbin. The first flat bobbin machine was a single tier. I carried up the threads by means of a steeple top on the carriage. Great difficulty was experienced in getting bobbins and carriages thin enough, the space in which they were to move being so limited. At last I was driven to the double tier, and thus obtained the requisite space." This, when perfected, became the double-tier "Old Loughborough machine," so called from the place where it was constructed; it was able to make lace of any breadth required. This was the first successful traverse bobbin-net machine, and brought to its inventor, along with a great amount of litigation in order to protect himself from infringements of his rights, a very handsome competence.

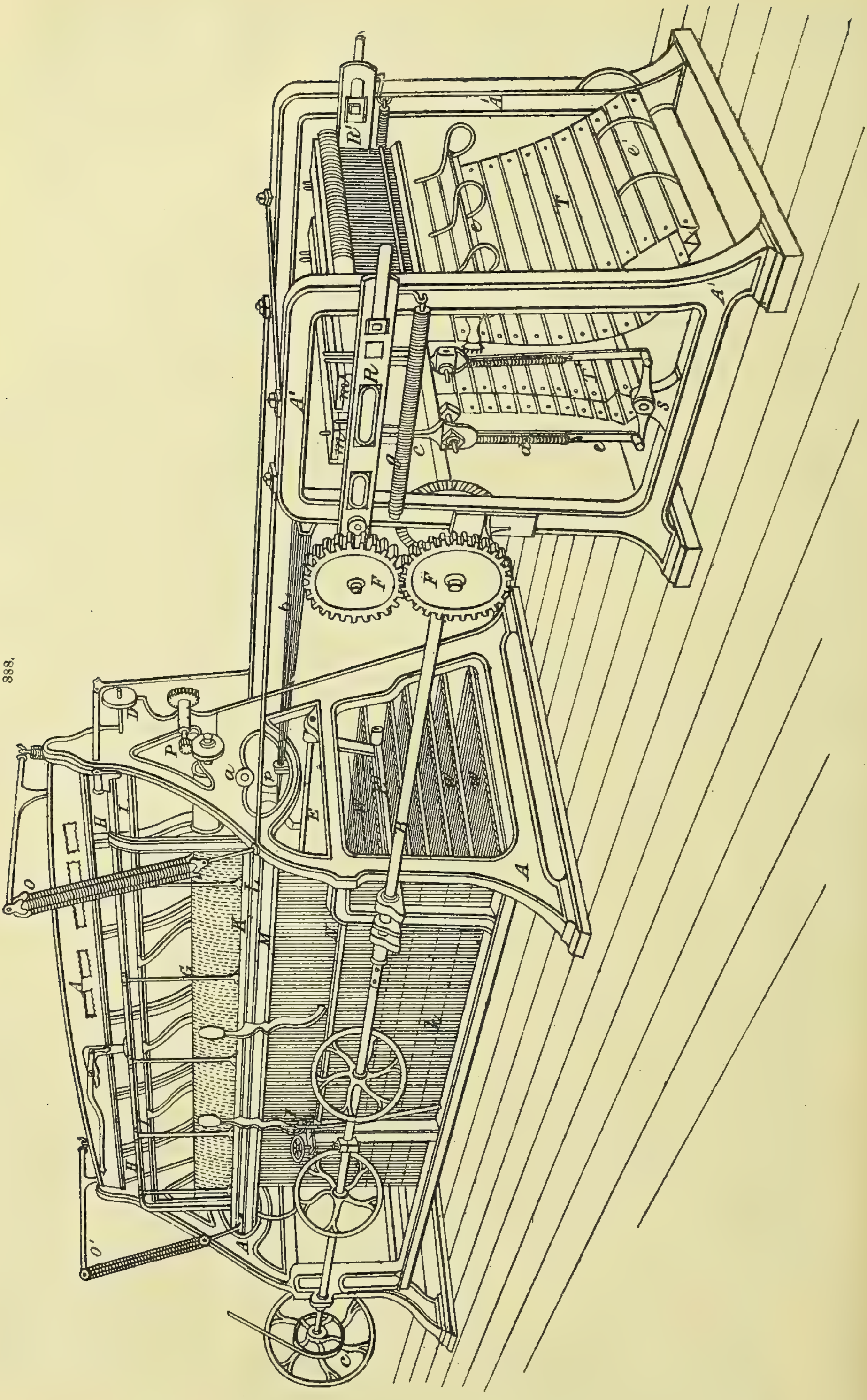
Like all successful inventors, Heathcoat had numerous imitators, some of whom, by a rearrangement of the parts of his machine, sought to deprive him of the merits and reward of his invention; others again, stimulated by his success, sought to improve his machine in many respects, or supersede it by entirely new inventions. One of the most successful of the former was Brown's traverse warp-machine. This and several others were successfully worked for some years, owing to the discovery of a serious flaw in Heathcoat's specification, during the progress of a trial in an action brought by the latter to defend his rights. Soon after this, Moore invented a traverse warp-machine embodying considerable mechanical skill, which caused an action to be brought against him by Brown. The case was tried, and the principal result, though not the one sought, was to establish the validity of Heathcoat's invention, and to compel both parties to acknowledge his priority, and each as a consequence submitted to pay a royalty to him for the use of their machines. The inventor and others continued to work at the improvement of this machine for many years, each alteration increasing its capacity or perfecting its work. It has suggested many other changes in lace machinery, and in that respect has contributed greatly to the wonderful development of the lace manufacturing industry of this country.

In 1812, a lace-frame was constructed, called the pusher-frame, which with subsequent improvements has been worked with advantage to a considerable extent. It was the invention of Clark and Mart of Nottingham. It possessed some special advantages, and is stated to have been a clever modification of Heathcoat's machine.

But the most important outcome of the inventive faculty, which was being so extensively utilized in the Midland districts was the bobbin-net machine of John Levers, another modification of the Old Loughborough machine. This appeared in 1813, and from that date to the present time has continued in use, and has gained ground over all competing machines to such an extent as to have become the leading machine employed in the trade. Levers was originally a frame-smith, and, like many others, encouraged by Heathcoat's success, devoted himself to the improvement of the methods in vogue for the production of lace. His success was remarkable, but he did not possess the high qualities of personal character that distinguished Heathcoat, and so failed to secure corresponding advantages. His machine was subsequently improved by numerous persons, but to detail these would be somewhat tedious. A better course will be to describe the machine in its present perfected form, as the best representative that could be selected of the mechanical lace frame.

The inventor of the Levers' lace-frame held the opinion that as it passed out of his hands it was only in its infancy. This was an accurate observation, for what with subsequent improvements, and the successful application of the jacquard attachment, its capacity has been extended so greatly, that hardly any limit can be put to its power. It is the most delicate of all the lace-making machines, its interior parts occupying the smallest space, and requiring the nicest adjustment. When arranged to make fancy work, it is also the most costly. A 10-point machine is about

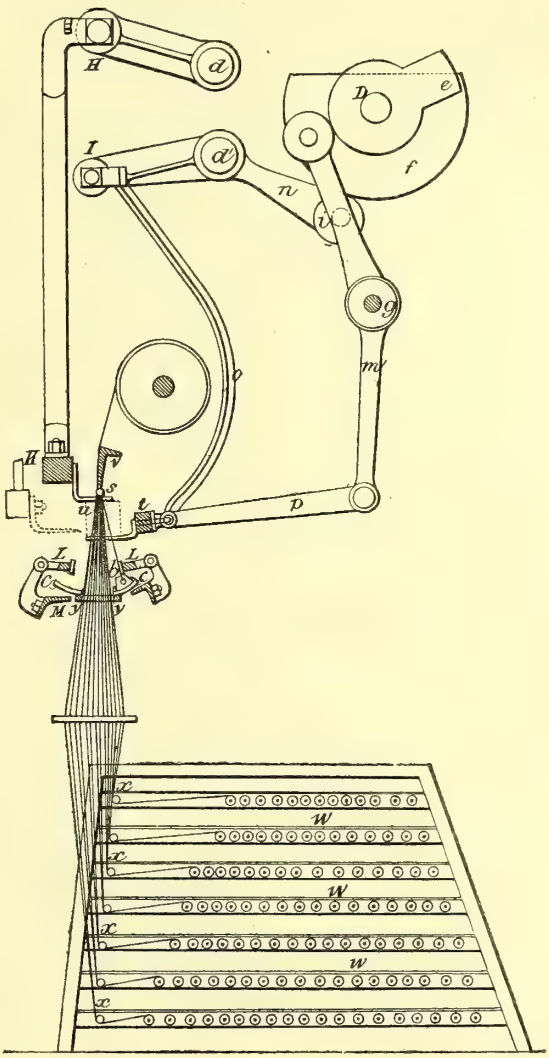
888.



152 in. in width, has 80 top bars, 400 bottom bars, 54 threading-beams, and a jacquard to enable it to produce ornamented laces. The framework is heavy and solid; its parts are highly finished, and its movements accurately adjusted: conditions essential to the satisfactory working of a lace-machine.

In Fig. 888, a general view of the machine with the jacquard attachment is given; the latter constitutes the right-hand part of the figure, whilst the left is the lace-frame proper. The frameworks of both the machines A A′ are massive, strong, and firmly attached to the flooring, in order to prevent vibration. The two parts are connected, and both actuated by the shaft B, which is driven by a strap on the pulleys *c*, near which is also fixed a balance- or fly-wheel, designed to secure steadiness in working. A shaft D arranged near the top of the back part of the frame carries several cams, and hence is called the cam-shaft; it is driven by means of a connecting shaft and wheels at the driving end of the frame. A shaft E extends the length of the frame, and by means of the connecting-rod E′, is rocked by cranks on the shaft B. Movement is imparted to the jacquard from the shaft B, through the wheels F. The sectional view, Fig. 889, will help to show the movements. The warp-beams *w* extend across the length of the frame, and contain the traversing threads of the fabric, each of which passes through eyelet-holes on the bars at *x*, and thence are conducted upward through the plate N and the slide-bars *y y*, and attached to the lace-beam C, which receives and winds up the lace as it is made. The bobbin in its carriage is shown at *b*, the thread from which passes up to the point *s*, the centre of the arc or oscillatory traverse in which the shuttles move. The carriages slide between the comb or guide-plates *c*, and as they pass from one comb-bar to the other, they necessarily go between the vertical warp threads. There is an angle-bar at M, and a corresponding one on the opposite part of the frame; these receive the carriages, which protrude through the comb-bar, as they pass through the warp threads, and are called landing-bars. The office of these bars is to receive the carriages, and diminish the friction that would otherwise arise from their large number, amounting to nearly 3000 in a frame of this description and width. Each landing bar has affixed to it at L a catch-bar, having a strip or blade which falls into slots *f* of the carriage Fig. 890, by which means the whole of the carriages are drawn across. On being returned to the opposite side, the catch-bar pushes them forward until within reach of the bar on the other side, the blade of which drops into the groove; the bar being withdrawn, brings with it the carriages. By these means, the carriages are transferred from one side to the other. The advance and recession of the landing- and catch-bars are accomplished by means of the rocking-shaft E, Fig. 888. These constitute the movements of the bobbins carrying the longitudinal threads of the fabric.

889.



The traversing or warp threads are operated very differently. From the beams *w*, they are conducted through the eyelets *x* upward, through the plate N, thence through the slide-bars *y*, whence they pass upward, and are attached to the lace-beam G. The slide-bars *y* are perforated to receive the threads. There are 100 of these bars in a machine such as represented here, and the threads are concentrated in them in sets or stops, as required by the design, and it is from these that the designer measures the distance that the threads must be deflected or drawn aside by the action of the jacquard.

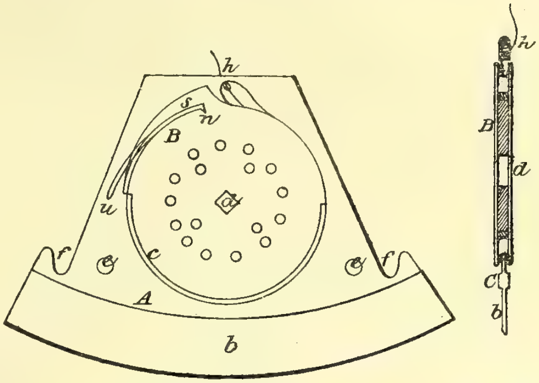
The lace-machine jacquard is specially constructed for the purpose, and differs in nearly all its details from that used in ordinary weaving. Each thread having to be moved through a known yet varying space, this is accomplished by using a series of wedges differing in size, which, being inserted between a sliding bar and a stud fixed upon each of the slides, is enabled by the movement of the bar to push the slide a distance corresponding to the size of the wedge which is adapted to the requirement of the pattern. The series of wedges consists of five: by the use of the first, the threads in the slides can be deflected over the space occupied by one bobbin in its carriage; by the second, two such spaces can be traversed; by the third, four; by the fourth, eight; the fifth being a repetition. The series thus stand in this order, 1, 2, 4, 8, 8; by the use of these, the warp threads can be deflected over any number of these "gates" from one to sixty-four.

The slide-bars (*b*, Fig. 888) are thin strips of fine steel, and contain holes for the passage through them of the warp threads. They are so thin that 100 do not occupy the space of an inch when set edgeways, the way they work, and yet allow space between them for the passage and deflection of the threads. The extremities away from the jacquard are attached to spiral springs, the opposite ones being connected with the slides of the jacquard, which move freely in sustaining guide-bars. Each bar at its extremity is furnished with a vertical projection or hook, which is for the purpose of preventing the spiral springs drawing them too far back after the action of the jacquard, the sustaining guide-bars arresting them at this point. Each bar also possesses two studs on its upper edge. The bars move simultaneously in opposite directions, according to requirement, and whilst in movement, have the wedges inserted between in such order as may be requisite; these are regulated by the action of the two series of cards T T′, one being all the odd numbers, and the other the even. The jacquard possessing a double action enables the speed of every part to be accelerated in proportion, the pace being double that of the single action. The cylinders are worked in the ordinary manner, and the wedges are fixed on the ends of thin flat springs, and have their lower ends made round in order to pass through the holes in the cards when required. The card-cylinders are actuated by a rocking-shaft, which alternately raises and lowers them for the purpose of changing the cards. The cylinders, as they rise, raise the two series of wedges, unless the cards present perforations into which their lower extremities enter. The cards are numbered on their margins, showing the spaces over which the sliding-bars operated by them can be moved, and which figures indicate the wedges that are required to be raised by them, either singly or in combination. The cylinders and wedges have also a lateral movement in connection with the slide-bars, which is arranged in order to keep the wedges in position. The slides are shown in Fig. 888, fitted between the cross-bars R R′, which are actuated by cams fixed on the shaft driven by the gearing F. A pair of these bars are fitted to each side of the jacquard, and the slide-bars *m* are mounted upon the top. The spiral springs *g* are for the purpose of returning the slides to the first position, after the revolution of the cams. The compound jacquard has lately come into wide use; it has a third set of cards for working the "thick" threads that outline the patterns. The cards of the jacquard are about 30 in. long by 2⅛ in. broad, and contain as many rows of holes as there are needles of the jacquard, with the addition of those required to form the selvages at each side of the lace web.

Each thread in a fabric of lace has a separate beam or bobbin; and both are nicely regulated, so that the pace or delivery of the yarn shall not be greater than the requirement. The beams, of which there may be 100, or any other number according to the quantity of threads required to form the pattern, have a small pulley fixed upon one end, around which a cord is passed one or more times, according to the amount of tension that may be needed, to the end of which a weight is attached, or it may be secured by a spring. The beams are tin tubes about 1½ in. in diameter, having small gudgeons at each extremity, on which they revolve. According to the number of times the pattern is repeated in a breadth of lace, or the number of separate breadths that may be produced at a time, will be the number of beams; for, should it be a narrow edge or insertion lace which requires 100 warp threads, and there are say 60 breadths being woven, the corresponding threads in each pattern, requiring to be delivered alike in each instance, can be all put upon one beam, and thus the 6000 threads in 60 patterns may be accommodated upon 100 beams.

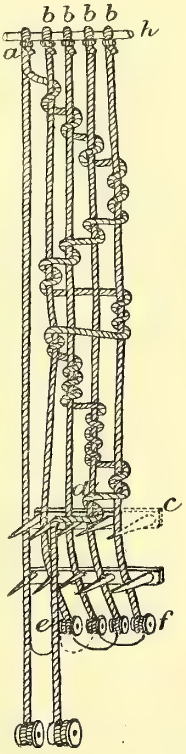
The other threads are individually provided for, being wound upon bobbins, which are formed of two thin discs of brass, about 2 in. diameter, joined by pins, and having a very small space between for the reception of the thread. When the bobbin is placed in the carriage, the end of the thread is drawn from it, and passed through a small hole as at *h*, Fig. 890, which shows the carriage and bobbin together. The former is made of thin steel, highly polished, cut in the shape shown, and having a circular hole in the centre for the bobbin. On the lower half of the circle, a thin flange *c* is adapted to fit between the discs of the bobbin, in order to secure it in position. The spring *s*, which is riveted into the carriage at *u*, has a projection or nib at *n*, which, passing between the discs, and pressing the bobbin upon the flange *c*, imparts the necessary tension to the thread as it is drawn off the bobbin. When the bobbins are filled, they are subjected to heat and pressure, which removes any slight inequality in thickness that may arise from filling, or other incidental causes. The bobbins are filled by placing them upon a spindle fitting the hole in the centre, and contain from 100 to 150 yards of thread, or more, according to fineness. The section of the carriage is shown much thicker than the reality, in order better to display its structure. The outline shows the carriage as a whole. The bottom part *b*, as will be seen in the section, is made thinner in order to pass easily between the divisions of the combs. The hooks *f* are termed drawing-hooks, being those into which the blades of the catch-bars drop, when the carriages are being passed through the warp, and drawn upon the landing-bars. The holes *e* are for the purpose of facilitating the withdrawal of the carriages when the bobbins are nearly empty. A wire is passed through the holes of a large number, and several hundred at a time are lifted from the frame.

890.



In operation, as the bobbins pass to and fro through the warp threads, around which the threads they carry are twisted, it is necessary that the portions of lace thus formed should be removed from the way of succeeding operations. This is accomplished by the action of the point or fork-bar K (Fig. 889) inserted into the warp beneath the twisting formed upon the threads, and then by the action of the cranks and levers is made to pull together in an upward direction the twisted threads, in order that the process may be continued. There are two of these combs acting alternately, as shown. After each movement, they are completely withdrawn, in order to be out of the way of the lateral movement of the warp threads.

891.



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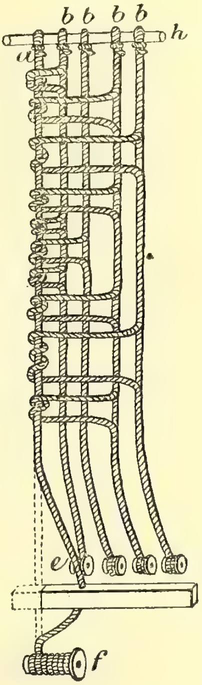


A simple illustration will dispense with a lengthy explanation. In Fig. 891, is a representation of five threads suspended from a rod *h*. The warp thread *a* has only a slight tension put upon it, compared with that upon the others. The four bobbins *e*, holding the remaining portion of the threads *b*, are intended to be represented as oscillating in the direction of the curved lines beneath them, the point from which they move being in a vertical line from the point from which they are suspended. These threads in a state of oscillation represent the motion of the carriages containing the bobbin threads when the machine is at work. Whilst the threads oscillate without any movement of the thread *a*, no effect is produced, the threads retaining the same relationship as before. But if, during the oscillation of the four threads *b*, the thread *a* be drawn laterally across the line being traversed by the bobbins, it will become twisted round the threads *b*. In this manner, the various threads round which the thread *a* has been twisted correspond to the lateral extent that it has been moved at each oscillation of the threads *b*. The function of the fork or comb has been previously explained. After each twisting, the greater tension of the threads *b* causes the thread *a* to be retained in the position to which it has been drawn, it not having power to deflect the threads *b*. Fig. 892 shows the effect that would result from the relative tensions of the above-mentioned being reversed. The threads *b* are, after each oscillation, drawn completely aside by the greater tension upon the thread *a*, and the whole structure of the fabric is thus changed. It therefore depends largely upon nice adjustment of the tensions upon the two sets of threads in relation to each other for perfect embodiment of a design. Ordinary laces draw the yarn mostly from the warp threads; high classes, from the bobbins.

A lace web, as it appears in the frame in the process of manufacture, presents a very different aspect to what the same fabric does when taken out of the machine. One set of threads, those from the bobbins, assume a longitudinal order, and appear scarcely deflected from a straight line, whilst the warp threads are interlaced with the preceding, as seen in Fig. 891. When the fabric is taken out of the frame, and all tension is removed, the meshes assume the form of the design, and show its beauty, though not to the full extent.

The Levers' lace-machines are made from 5- to 15-point in gauge. A 10-point requires 20 warp threads per in. to produce traversed net, which needs a full warp. In this, there will be 20 bobbins and carriages per in., in the single tier on the central comb-bar. In making fancy goods, there will be thick threads moved a greater or less distance sideways in addition. Of these, there may be from 40 upwards in an inch. The machine makes about 100 "shogging" or lateral movements of the warp threads, and the twisting movements of the weft threads as they pass backward and forward or through and around the warp threads, which makes about one inch of lace per minute. The bobbins and carriages are driven at this pace through the maze of tight and for the most part very fine threads of cotton or silk, or even untwisted filaments of the latter, in spaces of $\frac{1}{10}$–$\frac{1}{20}$ in., according to the gauge, working side by side, clear of each other and of the threads through which they pass, and which threads have all, between each movement of the carriages, been themselves moved $\frac{1}{10}$–$\frac{1}{20}$ in., so as to vary the particular intervals through which the carriages pass. Were the least irregularity to occur in this lateral movement, the threads would all be broken, and the machine injured.

As this is being written, great efforts are being made in Paris to introduce a new lace-machine, which is said to imitate the work of the pillow-lace maker much more perfectly than any previous machine has done. Having scarcely got beyond the experimental stage, it cannot receive further notice here.

The subsequent processes through which lace fabrics usually pass are gasing, bleaching, and finishing. By the first, all the loose, fibrous portion of the threads is singed off in passing over or through gas-jets, so arranged as not to injure the fabric. Bleaching restores the colour, which has suffered from contact with the parts of the machine in the process of working. Dressing is the final operation to which lace is subjected. In this, it is sought to extend the meshes to their proper shape, and by the application of a mixture of gum, starch, or other sizing compounds, to stiffen it so as to prevent its collapse, and enable it to exhibit the form and design intended.

This section, the mechanical branch of the lace manufacture, owes its origin, to and still flourishes principally, in this country. English-made machinery has, however, been exported to a considerable extent, and still continues to go abroad, so that it is not improbable that new centres of the industry may be in course of formation which will at some future day, to a larger extent than at present, share with us the task of supplying the demand for mechanically produced lace.

The following statistics relating to this branch of the lace trade are taken from the most recent government Returns. They refer strictly to those portions which come under the regulations of the Factory Acts, and are subject to inspection. In this respect, they are an inadequate return. As many of the subordinate processes can be carried on either at home, or in buildings which do not come under factory regulations, these are omitted. If included, they would bring the number of employés here given to an aggregate fully 4–4½ times as great.

SUMMARY OF LACE FACTORIES, 1879.

Counties.	Registration Districts.	Number of Factories.	Number of Lace Machines.	Number of Persons Employed.		
				Males.	Females.	Total.
Wilts, Dorset, Devon, Cornwall, and Somerset	South Western	4	..	693	905	1,598
Leicester, Rutland, Lincoln, and Nottingham	North Midland	237	..	4,757	2,234	6,991
Derby	"	37	..	743	616	1,359
Gloucester, Hereford, Salop, Stafford, Worcester, and Warwick ..	West Midland	4	..	72	144	216
Scotland. Ireland (none)	South Western	1	..	18	27	45
Total for 1879	..	283	..	6,283	3,926	10,209
Corresponding returns for 1874	..	311	3,462	6,945	3,428	10,373

From these figures, it will be seen that, during the five years which elapsed between the returns, there had been a small decline in the number of factories, and of the persons employed in the industry; but probably this was only a temporary falling off, owing to the severe depression of trade from which the country was suffering at the time the latest return was made. Of closed establishments, the enumerators took no account. Unfortunately there is also another important omission in the fact that no enumeration was made of the machinery, as in 1874. R. M.

LEATHER (Fr., *Cuir;* Ger., *Leder*).

The manufacture of leather is of very considerable importance, the capital invested in it in the United Kingdom having been some years since estimated at 30,000,000*l.* It is, however, very difficult to obtain any reliable statistics on the subject, the trade being now entirely free from excise restrictions, which were removed in 1830, when the duty realized amounted to 411,000*l.* Some idea of the expansion of the trade may be formed from the fact that while at that date the total export of leather and saddlery of British manufacture amounted to less than 200,000*l.*, during the year 1880, it was upwards of 3,300,000*l.*

The only information within reach as to the present extent of the trade is that which may be derived from the Board of Trade Returns of imports and exports, and from this it is exceedingly difficult to draw any definite conclusions, since large quantities of both leather and hides imported are re-exported, either in their rough condition or after manufacture. During the year 1880, the imports into the United Kingdom included upwards of 45,000,000 lb. of leather, in addition to 657,262 cwt. of dry hides, and 592,249 cwt. of salted. In the same period, were exported 346,554 cwt. of dry, and 85,213 cwt. of salted hides, leaving 310,708 cwt. of dry, and 507,036 cwt. of salted hides for tannage, in addition to the cattle killed in the United Kingdom. Of these, there were 343,659 imported, besides the very large number reared at home.

The principal sources of the leather imported into the United Kingdom are America, Australia, and the E. Indies, the two former sending sole-leather, and the latter the small hides known as "E. India tanned kips," which are used for dressing and insole purposes. Of these, 1,691,749 were sold in 1877, and 1,998,543 in 1878; but only 1,094,984 in 1879, and 846,267 in 1880.

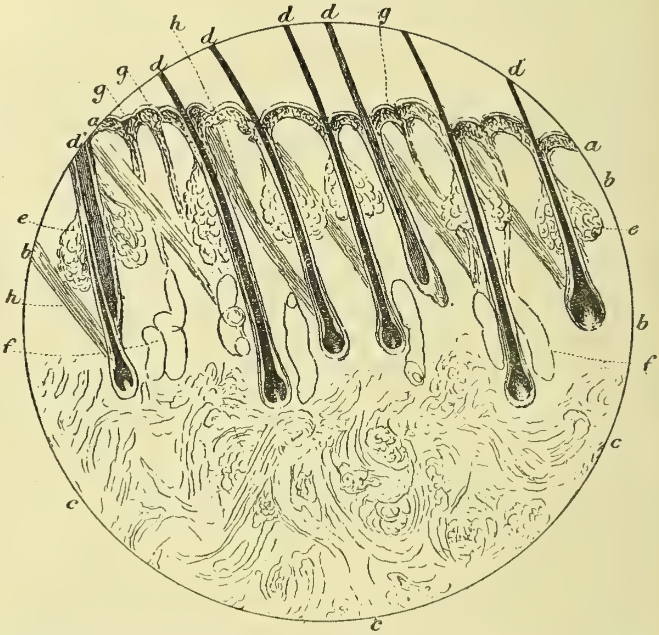
The principal seats of the heavy sole-leather manufacture from salted hides are Bristol and Warrington; light sole-leather is largely made in Bermondsey; while Leeds is famous for the tannage of E. India kips. Tanning is, however, by no means confined to these districts, many important tanneries being scattered over the country.

Leather manufacture may be broadly divided into two stages: "tanning," in which the raw hide is converted into the imputrescible and more or less flexible material known as "leather"; and "currying," in which this leather is further manipulated, and treated with fatty matters, to soften and render it more waterproof, and to improve its appearance. Glove-kid, and certain other leathers, however, are not tanned at all, but "tawed," or prepared with a mixture in which alum and salt are the most active ingredients; and many leathers can scarcely be said to be curried, although more or less oil is used in the final processes of "finishing" or "dressing." The first subject to be treated of in this article will be the operation of tanning, properly so called, taking for example the tannage of sole- and belting-leather. This demands thorough explanation, in both its practical and theoretical aspects, not only because it is one of the most important branches of the trade, but because the principles involved are those which equally underlie all other tanning methods. The next to be dealt with will be the modifications of the process which are necessary in tanning the more flexible leathers used for boot-uppers, hose-pipes, and saddlery purposes; then the currying of these leathers; and finally, the manufacture of moroccos, Russian, and japanned leathers, and calf- and glove-kid.

Anatomical Structure of Hide.—Before speaking of actual processes of manufacture, it is necessary to devote some attention to the structure and chemical constitution of hide or skin, which forms the raw material. Although a great variety of skins are employed in tanning, they are all constituted on the same general type, and an anatomical description of the hide of the ox will apply almost equally to those of the calf, sheep, and goat; but from differences in thickness and closeness of texture, their practical values differ widely. Fig. 893 shows a section of ox-hide, cut parallel with the hair, magnified about 50 dia.: *a*, epithelial layer or *epidermis*, consisting of horny layer above, and *rete malpighi* below; *b*, *pars papillaris*, and *c*, *pars reticularis* of *corium*, *derma*, or true skin; *d*, hairs; *e*, sebaceous or fat-glands; *f*, sudoriferous or sweat-glands; *g*, opening of ducts of sweat-glands; *h*, *erectores pili* muscles, for erecting the hair.

The fresh hide consists of two layers: an outer, the epidermis; and an inner, the true skin. The epidermis is very thin as compared with the true skin which it covers, and is entirely removed preparatory to tanning; it nevertheless possesses important functions. It is shown in Fig. 893 at *a*, and more highly magnified in Fig. 894. Its inner mucous layer *b*, the *rete malpighi*, which rests upon the true skin *c*, is soft, and composed of living nucleated cells, which are elongated in the deeper layers, and gradually become flattened as they approach the surface, where they dry up, and form the horny layer *a*. This last is being constantly worn away, and thrown off as dead scales of skin; and as constantly renewed from below, by the continued multiplication of the cells. It is from this epithelial layer that the hair, as well as the sweat- and fat-glands, are developed. It will be seen in Fig. 893 that each hair is surrounded by a sheath, which is continuous with the epidermis. In embryonic development, a small knob of cells forms on the under side of the epidermis, and this enlarges, and sinks deeper into the true skin, while the root of the young hair is formed within it. Smaller projections also form on the stalk of the knob, and in due time produce the sebaceous glands; this is shown in Fig. 895, *a b*. The process of development of the sudoriferous glands is very similar to that of the hairs. There is a great analogy between this process and that of the ordinary renewal of hair in the adult animal. At *d'*, Fig. 893, is seen an old and worn-out hair. It is shrunken and elongated, and is almost ready to fall out. It will be noticed that its sheath or follicle projects somewhat below the hair to stage of the right. This is the first production of a young hair, and is quite analogous to the knob of epithelium which has been described as forming the starting point of a hair in the embryo. At *d''*, the same process is seen further advanced, the young hair being already formed, and growing up into the old sheath. At *d'''*, it is complete, the old hair having fallen out, and the young one having taken its place.

893.



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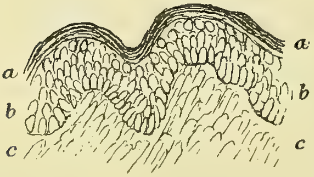

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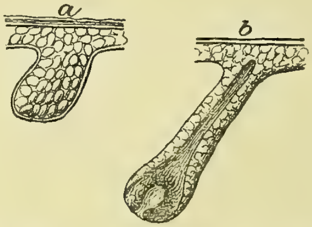
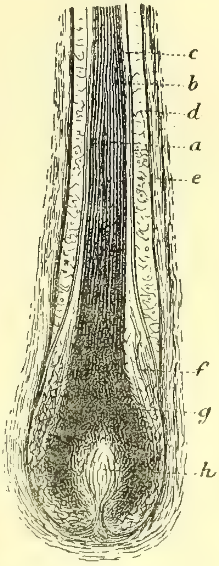


The hair itself is covered with a layer of overlapping scales, like the slates on a roof, but of irregular form. These give it a serrated outline at the sides, strongly developed in wool. Within these scales, which are sometimes called the "hair cuticle," is a fibrous substance, which forms the body of the hair; and sometimes, but not always, there is also a central and cellular pith, which is mostly transparent, though under the microscope it frequently appears black and opaque, from the optical effect of imprisoned air. On boiling or long soaking in water, alcohol, or turpentine, these air-spaces become saturated with the liquid, and then appear transparent.

The fibrous part of the hair is made up of long spindle-shaped cells, and contains the pigment which gives the hair its colour. The hair of the deer differs from that of most other animals in being wholly formed of polygonal cells, which, in white hairs, are usually filled with air. At its base, the hair swells into a bulb, which is hollow, and rests on a sort of projecting knob of the *corium* called the hair-papilla. This has blood-vessels and nerves, and supplies nourishment to the hair. The hair-bulb is composed of round, soft cells, which multiply rapidly; as they grow, they press upward through the hair-sheath, become elongated and hardened, and form the hair. In dark hairs, both the cells of the hair itself and those of its follicle or sheath are strongly pigmented, but the hair much the more so, and hence the bulb has usually a distinct dark form. The dark-haired portions of a hide from which the hair has been removed by liming still remain coloured, from the pigmented cells of the hair-sheaths, which can only be got out by bating and scudding. The cells outside the bulb shown at *f*, in Fig. 896, pass upwards as they grow, and form a distinct coating around the hair, which is called the "inner root-sheath." This again consists of two separate layers, of which the inner is "Huxley's," the outer, "Henle's." They arise from the same cells in the base of the hair; but in the inner layer, these remain polygonal and nucleated, while in the outer, they become spindle-shaped and without nuclei. The inner root-sheath does not extend to the surface of the skin, but dies away below the sebaceous glands. This figure represents an ox-hair root, mag. 200 dia.: *a*, fibrous substance of hair; *b*, hair cuticle; *c*, inner root-sheath; *d*, outer root-sheath; *e*, dermic coat of hair-sheath; *f*, origin of inner sheath; *g*, bulb; *h*, papilla.

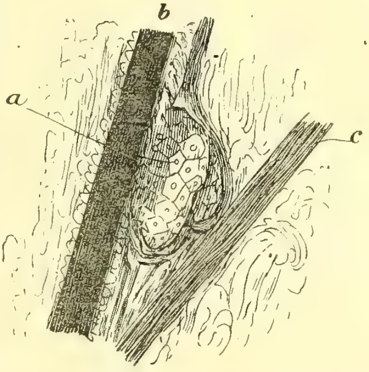
896.



Outside the inner root-sheath is a layer of nucleated cells, continuous with those of the epidermis, and of the same character. This is the "outer root-sheath," and is shown at *d*, Fig. 896. This, together with the whole of the epidermis, is covered next the *corium* with an exceedingly fine membrane, called the "hyaline" or glassy layer. The whole of the hair-sheath is enclosed in a coating of elastic and connective-tissue fibres, which are supplied with nerves and blood-vessels, and form part of the *corium*. Near the opening of the hair-sheaths to the surface of the skin, the ducts of the sebaceous or fat-glands (*e*, Fig. 893), pass into them, and secrete a sort of oil to lubricate the hair. The glands themselves are formed of large nucleated cells, arranged somewhat like a bunch of grapes; one is shown highly magnified in Fig. 897: *a*, sebaceous gland; *b*, hair-stem; *c*, part of *erector pili* muscle. The upper and more central cells are most highly charged with fat, which is shown by the darker shading.

As already remarked, the sudoriferous or sweat-glands are also derived from the epidermis layer. They are shown at *f*, Fig. 893, and on a larger scale (200 dia.) in Fig. 898: *a*, windings laid open in making section; they consist, in the ox and sheep, of a large wide tube, sometimes slightly twisted. In this, they differ considerably from those of man, which form a spherical knot of extremely convoluted tube. The walls of these glands are formed of longitudinal fibres of connective tissue of the *corium*, lined with a single layer of large nucleated cells, which secrete the perspiration. The ducts, which are exceedingly narrow, and with walls of nucleated cells like those of the outer hair-sheaths, sometimes open directly through the epidermis, as shown at *g*, but more frequently into the orifice of a hair-sheath, just at the surface of the skin. Each hair is provided with a slanting muscle (*h*, Fig. 893), called the *arrector* or *erector pili*, which is contracted by cold or fear, and causes the hair to "bristle," or stand on end; by forcing up the attached skin, it produces the effect known as "goose-skin." The muscle, which is of the unstriped or involuntary kind, passes from near the hair-bulb to the epidermis, and just under the sebaceous glands, which it compresses.

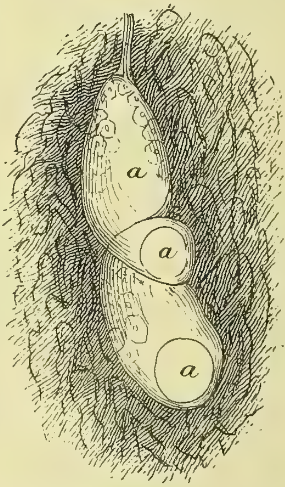
897.



The *corium* or true skin is principally composed of interlacing bundles of white fibres, of the kind known as "connective tissue"; these are themselves composed of fibrils of extreme fineness, cemented together by a substance of different composition from the fibres themselves. This may be demonstrated by steeping a small piece of hide for some days in a stoppered bottle in lime-, or baryta-water, in which the interfibrillar substance is soluble, and then teazing a small fragment of the fibre with needles on a glass microscope-slide, and examining with a power of at least 200-300 dia. In the middle portion of the skin, these bundles of fibre are closely interwoven; but next the body, they gradually become looser and more open, forming the *pars reticularis* (or netted part); and the innermost layer is a mere network of loose membrane, generally loaded with masses of fat-cells. It is this which is removed in the "fleshing" process. On the other hand, the outermost layer, just beneath the epidermis, is exceedingly close and compact, the fibre-bundles that run into it being separated into their elementary fibrils, which are so interlaced that they can scarcely be recognized. This is the *pars papillaris*, and forms the lighter-coloured layer, called the "grain" of leather. It is in this part that the fat-glands are embedded, while the hair-roots and sweat-glands pass through it into the loose tissue beneath.

Besides the connective-tissue fibres, the skin contains a small proportion of fine yellow fibres, called "elastic" fibres. If a thin section of hide be soaked for a few minutes in strong acetic acid, and then examined under the microscope, the white connective-tissue fibres become swollen and transparent, and the yellow fibres may then be seen, as they are scarcely affected by the acid. The hair-bulbs and sweat- and fat-glands are also rendered distinctly visible.

898.

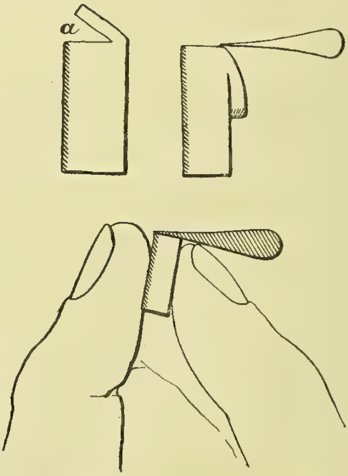


The nerves of the skin are very numerous, each hair being supplied with fibres passing into both the papilla and sheath. They also pass into the skin papillæ. They cannot readily be seen, without special preparation, and so far as is known, exercise no influence on the tanning process. "Breaking the nerve" is a technical term, which signifies a thorough stretching and softening of the skin, but has nothing to do with nerves properly so called. The blood- and lymph-vessels are, from the present point of view, somewhat more important. They may often be seen in sections, and are lined with nucleated cells, similar to those of the glands. These are surrounded by coatings of unstriped muscular fibre, running both around and lengthways, and also by connective-tissue fibres. In the arteries, the muscular coating is much stronger than in the veins.

It may be thought that the space above devoted to the anatomical structure of the skin is disproportionately large; but there can be no doubt that, in order to make improvements, nothing is of more importance than a clear conception, even to the smallest details, of the materials and causes to be dealt with. The illustrations are from actual specimens, and enable the various parts of the hide to be identified under the microscope, which instrument is destined to play a most important part in the development of tanning.

If it be required to see how far the cellular structure of the hide, such as hair-sheaths and fat-glands, are affected or destroyed in any stage of liming or bating, the following ready method may be employed. If a strip of hide be cut $\frac{2}{3}$ through from the grain side, as shown at *a* in Fig. 899, and the flap be turned down, and held between the finger and thumb, the fibrous tissue will be put on the stretch, and will then allow a moderately thin shaving (including the grain and parts immediately below it) to be cut by a sharp razor. The hide should be held in the position shown, and a steady drawing cut be made from flesh to grain, the razor being steadied on the tip of the forefinger, and its hollow surface flooded with water. If the thin section be now placed on a glass slide, moistened with a drop of water, and examined on the microscope under a strong light from above, with a 1-in. objective, the fat-glands will be seen as yellow masses, embedded in the white fibrous tissue. If a drop of a mixture of equal vols. of strong acetic acid, glycerine, and water be used to moisten the section, the fibrous tissue will become quite transparent, and whatever remains of the cellular tissue will be easily visible, and may even be studied under tolerably high powers if covered with a thin glass, and lighted by the mirror from below.

899.



The same method is applicable for ascertaining the completeness of the tannage of leather, and to decide whether the hide fibre is really tanned, or only dyed. Actually tanned leather is unaffected by the acetic acid, but raw or only stained hide swells and becomes transparent.

To prepare the very thin sections necessary for detailed study of the hide, more complicated methods are required. Small slips of hide, not exceeding $\frac{1}{4}$ in. wide, and cut directly across the lie of the hair, are placed first in weak alcohol (methylated spirit and water), and, after a few hours, are removed into strong methylated spirit. In 24 hours, the hide is hard enough to give fine shavings, and may be cut either when held as above described, or when embedded in paraffin wax. The razor must be wet with alcohol, and the section be made exactly in the plane of the hair-roots, which may be seen with a hand-lens. The slices may now be stained by placing them in a watch-glass with water and a few drops of the logwood or picrocarmine staining-mixtures sold by opticians, and afterwards either examined in glycerine, or, after soaking some hours in absolute alcohol, may be transferred to clove-oil, and afterwards to a slide, and covered with a drop of dammar varnish and a cover-glass for permanent preservation. If picrocarmine be used, the connective-tissue fibres (gelatinous fibres) and the nuclei of the cells will be coloured red, and the cells themselves of both epidermis and glands, together with the muscles and elastic fibres, will be yellow.

For further information, the reader is referred to microscopic manuals, such as Schaefer's 'Practical Histology.' Some important researches on the structure of hide, and its modification in tanning, have been made by F. Kathreiner, of Worms, who has invented refined and convenient methods of microscopic research, specially adapted to the purpose. Particulars of these are in course of publication.

Chemical Composition of Hide.—The chemical composition of skin is very imperfectly understood. The bulk of the skin is, as has long been known, converted by boiling into gelatine or glue. The yellow fibres and cellular tissue remain undissolved. Müntz, who made some interesting researches on the subject, found that completely dried hide contained—3·086 per cent. of cellular tissue insoluble in hot water, 1·058 of fat, 0·467 of mineral matter, and 95·395 of matters soluble in hot water. Müntz counts the whole of the tissue soluble in hot water as converted into glue; but this is not strictly the case. Gelatine is not identical with the fibre of the hide, which is only converted into it by boiling. The nature of the change is not well understood; but it is either simply molecular, or depends on the addition of one or more molecules of water. Raw hide, unhaired and purified, contains, according to Müntz—carbon, 51·43 per cent.; hydrogen, 6·64; nitrogen, 18·16; oxygen, 23·06; ash, 0·71; while gelatine has, according to Mulder—carbon, 50·1 per cent.; hydrogen, 6·6; nitrogen, 18·3. Probably, however, neither substance was quite pure.

Gelatine is insoluble in alcohol, ether, and cold water, but swells in the last. It is soluble in hot water, but is reprecipitated on the addition of a sufficient quantity of alcohol. This reaction is common to gum, dextrine, and other substances. Moist gelatine exposed to the air rapidly putrefies. It first becomes very acid, from formation of butyric (and perhaps other) acids, but afterwards alkaline, from evolution of ammonia. Boiled with concentrated potash, it yields leucine, glycocine (sugar of gelatine), and other substances.

The same products are obtained by boiling with sulphuric acid, and probably also more gradually, and in greater or less proportions, by the prolonged action of lime or barium hydrate, by putrefaction, and by any other influence which tends to resolve the gelatine molecule into its simpler parts. Gelatine is precipitated by all tannins, even from very dilute solution. A solution containing $\frac{2}{100000}$ parts is rendered turbid by infusion of gall-nuts or gallotannic acid. The precipitate is soluble in excess of gelatine. Solution of gelatine dissolves considerable quantities of phosphate of lime, hence this is always largely present in common glue. It is not precipitated by ferrocyanide of potassium, by which it is distinguished from albuminoids, and it differs from albumen in not being coagulated by heat. On the contrary, by prolonged boiling, glue loses the property of gelatinizing, but is not altered in composition.

The connective-tissue fibres are partially converted into gelatine by the action of strong acids and alkalies, as well as by heat. By weak acids, they are swollen and gradually dissolved, and Reimer has found that the fibrous material may be reprecipitated by lime-water. It forms an irregular fibrous mass, which has not the sticky feel of gelatine, but is at once converted into the latter by boiling. Rollet has demonstrated that when hide and other forms of connective tissue are soaked in lime- or baryta-water, the fibres become split up into finer fibrils, and as the action proceeds, these again separate into still finer, till the ultimate fibrils are as fine as can be distinguished under a powerful microscope. At the same time, the alkaline solution dissolves the substance which cemented the fibres together, and this may be recovered by neutralizing the solution with acetic acid, when it comes down as a flocculent precipitate. This was considered by Rollet as an albuminoid substance; but Reimer has shown that it is much more closely allied to the gelatigenous fibres, if indeed it is not actually produced from them by the action of the alkaline solution. Reimer used limed calf-skin for his experiments, and subjected it to prolonged cleansing with distilled water, so that all soluble parts must have been pretty thoroughly removed beforehand. He then digested it in closed glasses with lime-water for 7–8 days, and precipitated the clear solution with dilute acetic acid. He found that the same portion of hide might be used again and again, without becoming exhausted, which strongly supports the supposition that it is merely a product of the partial decomposition of the hide fibre. The substance, which he called "coriin," was purified by repeated solution in lime-water, and reprecipitation by acetic acid. It was readily soluble by alkalies, but insoluble in dilute acids, though in some cases it became so swollen and finely divided through the latter as to appear almost as if dissolved. It was, however, very soluble in common salt solution of about 10 per cent., though it was precipitated both by the addition of much water, and by saturating the solution with salt. Reimer found that a 10 per cent. salt solution was equally effective with lime-water in extracting it from the hide, and that it was partially precipitated on the addition of acid, and completely on saturating the acidified solution with salt. Other salts of the alkalies and alkaline earths acted in a similar manner, so that Reimer was at first deceived when experimenting with baryta-water, because, being more concentrated than lime-water, the coriin remained dissolved in the baryta salt formed on neutralizing with acid, and it was necessary to dilute before a precipitate could be obtained. The slightly acid solution of coriin gave no precipitate with potassium ferrocyanide, nor was it precipitated by boiling, being thus distinguished from albuminoids. The neutral or alkaline solution was not precipitated by iron or mercuric chloride, copper sulphate, nor by neutral acetate of lead; but was precipitated by basic lead acetate, basic sulphate of iron, and excess of tannin. Its elementary composition is—carbon, 45·91; hydrogen, 6·57; nitrogen, 17·82; oxygen, 29·60; and Reimer proposes the following equation as representing its relation to hide fibre:—

$$\underset{\text{Hide fibre.}}{C_{30}H_{46}N_{10}O_{12}+O} \;+\; \underset{\text{Water.}}{2H_2O} \;=\; \underset{\text{Coriin.}}{C_{30}H_{50}N_{10}O_{15}}.$$

Hide Albumen.—The fresh hide, besides this coriin (which, very possibly, is only evolved by the action of the lime), contains a portion of actual albumen, viz. that of the blood serum and of the lymph, which is not only contained in the abundant blood-vessels, but saturates the fibrous connective tissue, of which it forms the nourishment. This albumen is mostly removed by the liming and working on the beam, which is preparatory to tanning. Probably for sole-leather, the albumen itself would be rather advantageous if left in the hide, as it combines with tannin, and would assist in giving firmness and weight to the leather. It is, however, for reasons which will be seen hereafter, absolutely necessary to get rid of any lime which may be in combination with it. The blood also must be thoroughly cleansed from the hide before tanning, as its colouring matter contains iron, and, in combination with the tannin, would give a bad colour.

The reactions of blood and lymph albumen are very similar to those of ordinary white of egg. It is precipitated by strong mineral acids, especially nitric, and also by boiling. The precipitate produced by strong hydrochloric acid re-dissolves by the aid of heat to a blue or purple solution. Tribasic phosphoric, tartaric, acetic, and most other organic acids, do not precipitate moderately dilute solutions of albumen, but convert it into a sort of jelly, which, like gelatine, does not coagulate, but liquefies on heating. It is precipitated by neutral salts of the alkali metals. Albumen slightly acidified (with acetic acid) is precipitated by potassium ferrocyanide.

Elastic Fibres.—The elastic or yellow fibres of the hide are of a very stable character. They are not completely dissolved even by prolonged boiling, and acetic acid and hot solutions of caustic alkalies scarcely attack them. Probably they do not combine with tannin, and are very little changed in the tanning process.

The hair, epidermis, and glands are, as has been seen, all derived from the epithelial layer, and hence, as might be inferred, have much in common in their chemical constitution. They are all classed by chemists under one name, "keratin," or horny tissue, and their ultimate analysis shows that in elementary composition they nearly agree. It is evident, however, that the horny tissues are rather a class than a single compound.

The keratins are gradually loosened by prolonged soaking in water, and, by continued boiling in a Papin's digester, are dissolved to an extract which does not gelatinize on cooling. Keratin is dissolved by caustic alkalies; the epidermis and the softer horny tissues are easily attacked, while hair and horn require strong solutions and the aid of heat to effect complete solution. The caustic alkaline earths act in the same manner as dilute alkaline solutions; hence lime easily attacks the epidermis, and loosens the hair, but does not readily destroy the latter. Alkaline sulphides, on the other hand, seem to attack the harder tissues with at least the same facility as the soft ones, the hair being often completely disintegrated, while the epidermis is still almost intact; hence their applicability to unhairing by destruction of the hair. Keratins are dissolved by fuming hydrochloric acid, with the production of a blue or violet coloration, like the albuminoids. They also resemble albumen, in the fact that their solution in sulphuric acid is precipitated by potassium ferrocyanide. By fusion with potash, or prolonged boiling with dilute sulphuric acid, keratin is decomposed, yielding leucine, tyrosine, ammonia, &c. The alkaline solution of keratin (hair, horns, &c.) is precipitated by acids, and, mixed with oil and sulphate of baryta, is employed under Dr. Putz's patent as a filling material for leather, for which purpose it acts in the same way as the egg-yolks and meal used in kid-leather manufacture. Eitner has also proposed its use for the same purposes with bark-tanned leather.

Hides used for Sole-leather.—The principal sources of hides for sole-leather are:—

(I.) Market hides, from the cattle slaughtered for food in the United Kingdom. These are received by the tanner, fresh or slightly salted, and are either bought directly from the butcher, or, now more commonly, through the auction markets established in all large towns. The latter system, while it perhaps slightly enhances the price of the hides to the tanner, ensures him a better classification according to weight, and, in some cases, as notably in that of Glasgow, a better flaying, through an organized system of inspection and sorting. The Scotch hides, being mostly from Highland cattle, are many of them small and very plump, for, as a rule, the hides are thickest on those animals which are exposed to cold and the hardships of out-door life. On the other hand, the hides of highly-bred cattle are apt to be thin and spreading; and, if they have been kept much indoors, and negligently managed, the grain of the hide is injured by the dung which adheres to it. The Irish hides are usually somewhat roughly flayed.

(II.) South American hides are from the River Plate, Uruguay, and Rio Grande. Those from the River Plate are considered the best, as being stoutest and finest in texture. They are usually cured by salting, and are known as "saladeros," "estancias," and "mataderos," according to the slaughter and cure. The saladeros are the best, and are from cattle killed at large slaughtering establishments on the coast. The estancias are from cattle killed in the interior, and are worse in flaying than the saladeros, but free from the objectionable dark cure of the mataderos, which are killed by the city butchers. Many hides are brought from Brazil, and are generally both salted and sun-dried, or simply stretched out and dried. Hides are also imported from Valparaiso, both dry and wet-salted.

China and W. Indies hides are mostly dried. French market hides have been of recent years largely imported; they are mostly well-flayed, and some of them very heavy, but are sold at original butchers' weight, and, in the experience of some tanners, the result in leather is 5–6 per cent. less than from English market hides. They usually lose about 25 per cent. in sculling and salting. Lisbon hides are often well flayed, but are frequently branded, and the grain is injured by insects. They yield considerably more leather than market hides in proportion to weight. Hambro hides are salted, but mostly wet and ill-flayed.

Preparation of Hides for Tanning.—Market hides merely require a slight soaking in fresh water, to remove blood and dirt, before unhairing. Salted hides should be soaked somewhat longer, and in several changes of water, so as to remove the salt before limeing. Dried hides, however, require more lengthened treatment. Before they are prepared for tanning, they must be brought back as far as possible to the condition of fresh hides, and, for this purpose, must be thoroughly soaked and softened in water. There are many ways of doing this: sometimes hides are suspended in running water; sometimes laid in soaks, which may be either renewed, or allowed to putrefy; sometimes in water to which salt or carbolic acid has been added, to prevent putrefaction.

The first of these methods, were it desirable, is rarely possible in these days of River Pollution Acts; of the others, it is difficult to say which is better, since the treatment desirable varies with the hardness of the hide and the temperature at which it has been dried. The great object is to thoroughly soften the hide, without allowing putrefaction to injure it. As dried hides are often damaged already from this cause, either before drying, or from becoming moist and heated on shipboard, it is frequently no easy matter to accomplish this. The fresh hide, as has been seen, contains considerable portions of albumen, and if the hide is dried at a high temperature, this becomes wholly or partially coagulated and insoluble. The gelatinous fibre and the coriin (if indeed the latter exists ready formed in the fresh hide) do not coagulate by heat, but also become less readily soluble. Eitner experimented with pieces of green calf-skin of equal thickness, which were dried at different temperatures, with results given in the following table:—

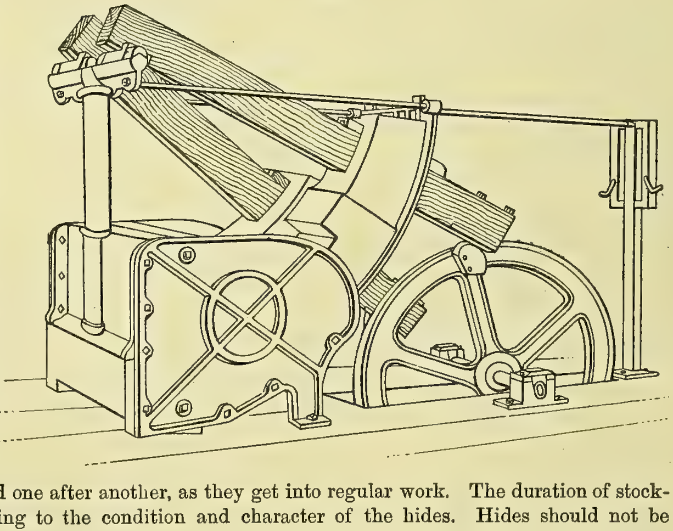
	Temperature of Drying.	Remarks.	Time of Softening in Water.	Remarks.	Coriin Dissolved by Salt Solution.
Sample I.	15° C.	In vacuo	24 hours	Without mechanical work	1·68 per cent.
„ II.	22° C.	In sun	2 days		1·62 „
„ III.	35° C.	In drying-closet	5 „	twice worked	0·15 „
„ IV.	60° C.	„	Refused to soften sufficiently for tanning		Traces.

Hence it is evident that, for hides dried at low temperatures, short soaking in fresh and cold water is sufficient, and, except in warm weather, there would be little danger of putrefaction. With harder drying, longer time is required, and it may be necessary to use brine instead of water. A well-known tanner recommends a solution of 30°–35° barkometer (sp. gr. 1·035, or about 5 per cent. of NaCl). This will have a double action, not only preserving from putrefaction, but dissolving a portion of the hide-substance in the form of coriin. Although this is undoubtedly a loss to the tanner, it is questionable if there is any process which will soften overdried hides without loss of weight: even prolonged soaking in cold water at too low a temperature to allow of putrefaction will dissolve a serious amount of hide-substance. Water containing a small quantity of carbolic acid has been recommended for the purpose, and will prevent putrefaction, while it has no solvent power on the hide, but, on the contrary, will coagulate and render insoluble albuminous matters. Borax has been proposed for the same purpose, and, in strong solution, certainly prevents putrefaction, but is probably too costly. Sulphide of sodium and other sulphides seem to have considerable effect in softening dried hides, from their property of attacking hard albuminous matters, without injuring the true hide-fibre. A little sulphide of sodium is sometimes added to obstinate hides in the stocks.

For some descriptions of hides, however, and notably for India kips, putrid soaks seem actually to be an advantage, the putrefactive action softening and rendering soluble the hardened tissue. Putrefactive processes are always dangerous, as the action, through changes of temperature, or variation in the previous state of the liquor, is apt to be irregular, and either to attack one portion of the hide before another, or to proceed faster than was expected. Hence hides in the soaks require constant and careful watching, and the goods must be withdrawn as soon as they are thoroughly softened, for the putrefaction is constantly destroying as well as softening the hides. It is probable that putrefactive softening is less injurious to kips, and such goods as are intended for upper-leather, than to those for sole purposes, as it is necessary in the former case that the albumen and interfibrillary matter be removed, and that the fibre be well divided into its constituent fibrils for the sake of softness and pliability; the putrid soak, if acting rightly, only accomplishes a part of the work, which would afterwards have to be done by the lime and the bate. The actual fibre of the hide seems less readily putrescible than the albuminoid parts; hence the putrefaction may soften the latter better, and even at less expense of valuable hide-substance, because more rapidly, than fresh water. On this point, there is room for investigation. Putrefaction is a general name for a class of decompositions which are caused by a great variety of living organisms, each of which has its own special products and modes of action. It is quite possible that, if we knew what precise form of putrefaction was most advantageous, we might by appropriate conditions be able to encourage it to the exclusion of others, and obtain better results than at present. It will be necessary to revert to this subject when speaking of the bates used in preparing dressing-leather, which also owe their activity to putrid fermentation.

Beside merely soaking the hides, it is necessary to work them mechanically, to promote their softening, which was formerly accomplished by "breaking over" the hides on the beam with a blunt knife. This process is now usually superseded or supplemented by the use of the "stocks"; these consist of a wooden or metallic box, of peculiar shape, wherein work two very heavy hammers, raised alternately by pins in a wheel, and let fall upon the hides, which they force up against the side of the box with a sort of kneading action. The ordinary form of this machine is shown in Fig. 900. A more modern form, which seems to possess some advantages, is the American double-shover, seen in Fig. 901.

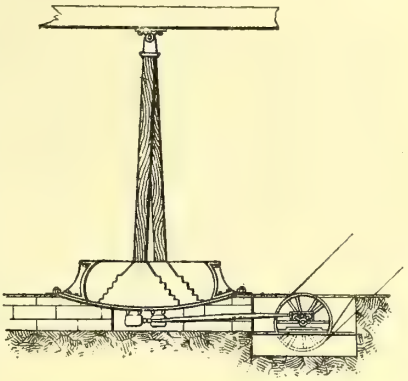
900.



The number of hides which can be stocked at once naturally varies with the size of both hides and stocks, but should be such that the hides work regularly and steadily over and over. The whole number should not be put in at once, but should be added one after another, as they get into regular work. The duration of stocking is 10–30 min., according to the condition and character of the hides. Hides should not be stocked till they are so far softened that they can be doubled sharply, without breaking or straining the fibre. After stocking, they must be soaked again for a short time, and then be brought into an old lime. A small quantity of sulphide of sodium added to the soaks or in the stocks has been recommended as of great value in softening obstinate hides, and probably with justice, from its well-known softening action upon cellular and horny tissues.

Unhairing.—In England, lime is the agent universally used for this purpose, though every tanner admits its deficiencies and disadvantages. It is hard, however, to recommend a substitute which is free from the same or greater evils, and lime has one or two valuable qualities, which will make it very difficult to supersede. One of these is that, though it inevitably causes loss of substance and weight, it is also impossible, with any reasonable care, totally to destroy a pack of hides by its use; this is by no means the case with some of its rivals. Another advantage is that, owing to its very limited solubility in water, it is a matter of comparatively small consequence whether much or little is used; and even if the hides are left in a few days longer than usual, the mischief, though certain, is only to be detected by careful and accurate observation. With all other methods, exact time and quantity are of primary importance, and it is not easy to get ordinary workmen to pay the necessary attention to such details. Again, the qualities of lime, its virtues and failings, have been matter of experience for hundreds of years, and so far as such experience can teach, we know exactly how to deal with it. A new method, on the other hand, brings new and unlooked-for difficulties, and often requires changes in other parts of the process, as well as in the mere unhairing, to make it successful. As our knowledge of the chemical and physical changes involved becomes greater, we may look to overcoming these obstacles more readily; this constitutes one of the main advantages of a really scientific knowledge over an empirical one.

901.



Slacked lime is soluble in water at 15° (60° F.) to the extent of 1 part in 778. Unlike most substances, it decreases in solubility at higher temperatures, requiring 972 parts of water at 54° (130° F.), and 1270 parts at 100° (212° F.). Its action upon animal tissues increases rapidly, however, with temperature, though no doubt it is moderated to some extent by the lessened solubility. Calculating from Dalton's numbers, pure lime-water at 15° (60° F.) contains 1·285 grm. of CaO per litre, and should require 459 cc. of decinormal acid to neutralize it. This estimate in some cases appears to be slightly too high; e. g. a saturated lime-water from carboniferous limestone at 13° (56·5° F.) required only 433 cc. of decinormal acid, which equals 1·211 grm. of CaO per litre, and this lime-water gave nearly constant results for many months together: on the other hand, any traces of other soluble bases would raise the strength of the lime-water above its normal amount. Thus a magnesian limestone lime-water tested at the same time required 472 cc. of $\frac{1}{10}$th normal acid, confirming the old observation of tanners, that such lime is stronger than that made either from chalk or carboniferous limestone. This increased strength must arise from the presence of some soluble base other than lime, and may be due to the magnesia, which, however, is very slightly soluble.

The action of lime on the hide has already been spoken of to some extent. This is throughout a solvent one. The hardened cells of the epidermis swell up and soften, the *rete malpighi* and the hair-sheaths are loosened and dissolved, so that, on scraping with a blunt knife, both come away more or less completely with the hair (constituting "scud," as some English tanners name it, Ger., *gneist* or *grund*). The hair itself is very slightly altered, except at its soft and growing root-bulb, but the true skin is vigorously acted on. The fibres swell and absorb water, so that the hides become plump and swollen, and, at the same time, the "cement-substance" (coriin) is dissolved, the fibres become differentiated into finer fibrils, and the fibrils themselves become first swollen and transparent, and finally corroded, and even dissolved. This swelling of the fibres is produced both by alkalies and acids, and is probably due to weak combinations formed with the fibre-substance, which have greater affinities for water than the unaltered hide. It is useful to the tanner, since it renders the hide easier to "flesh" (i. e. to remove the adhering flesh), on account of the greater firmness which it gives to the true skin. It also assists the tanning, by opening up the fibre, and so exposing a greater surface. This is advantageous only in dressing leather which is afterwards tanned in sweet liquors, and must have the cement-substance dissolved and removed for the sake of flexibility; but, in the case of sole-leather, it is probable that the same effect might be produced with less loss of substance and solidity by suitable acidity of the liquors. A more certain advantage of lime is that it acts on the fat of the hide, converting it more or less completely into an insoluble soap, and so hindering its injurious effects on the after tanning process, and on the finished leather.

The customary method of limeing is simply to lay the hides flat in milk of lime in large pits. Every day, or even twice a day, the hides are drawn out ("hauled"), and the pit is well plunged up, to distribute the undissolved lime through the liquor. The hides are then drawn in again ("set"), care being taken that they are fully spread out. Great differences exist in the quantity of lime used, the time given, and the method of working. Jackson Schultz prescribes 1 bush. (56 lb.) of fresh lime to 60–70 hides, and 3–4 days as sufficient time to unhair and plump them; while a well-known English tanner states that, after working for 6–10 days through a series of old limes, the hides (presumably wet-salted S. Americans) should have 4 days in a fresh lime, made with 3–12 lb. of lime per hide. It is obvious that if the American authority is right, the English process is wasteful in the extreme, both in hide-substance and lime. It is probable, however, that it would be found impossible to unhair and flesh hides, to suit the English market, in cold limes with the quantity and time mentioned, and if the limes are steamed, it is quite likely that the destructive action on the pelt may be even greater than by the longer and slower process in the cold. Most likely a compromise between the two is the most desirable, and about 2–4 lb. of lime per hide, according to weight, should be sufficient, while a week for market hides, and 14 days for heavy salted, will loosen the hair and plump the pelt as much as is requisite. This is on the supposition that the limes are kept at a uniform average temperature of about 15° (60° F.) in winter and summer. If they are heated to 27°–32° (80°–90° F.), of course much less time is required, but there are no published experiments showing the relative weights made by the two processes, and, from the fact that warmed limes are principally used for descriptions of leather where weight and solidity are not of primary importance, it may be concluded that, in this direction, the results are unsatisfactory.

Another undecided point is whether the best results are obtained by making fresh limes for every pack, or by strengthening up the old ones. An old lime becomes charged with decomposing animal matter and with ammonia, and, within limits, loosens the hair more effectually than a new one. An experienced tanner states that, by using old limes, better weights are obtained, but that the leather is thinner than when a fresh portion of lime is used, and this is quite in accordance with theory. If, however, the old lime-liquor be retained too long, it ceases to swell the hides as it should, and, in warm weather, the limeing proper is complicated by a putrefactive process allied in principle to sweating.

Several variations in the above-described method of limeing have been proposed. A well-known patent claims the plan of suspending the hides on laths, and agitating the liquor by plunging in place of hauling. Probably this is an actual improvement, especially if some mechanical agitating contrivance be substituted for hand plunging. It has, however, the drawback that much room is required, though this may be, to some extent, compensated by the hides limeing more quickly. As the method has been long in use in America, and had been tried in several places in England before the patent was obtained, it is not probable that it could be legally sustained, in this respect resembling a large proportion of the patents referring to leather manufacture. Two other American labour-saving methods in connection with limeing may be mentioned here. One is to have the limeing-vat double the ordinary size, and, instead of hauling the hides, to simply draw them from one side to the other by two strings, which are attached to the fore and hind shank of each hide. The strings are either looped over iron rods at the four corners of the pit, or have simple knots, which are placed in notches sawn in wood. Of course, while the hides are at one side of the pit, the other side may be plunged or warmed. The other method is to have a spindle with discs at each end, to which the hides or sides are attached by hooks set round the edges. The hides are wound up by turning the spindle with a handspike, and the whole spindle is also capable of being raised and lowered in the liquor.

An American plan, known as the "Buffalo method," is described by Jackson Schultz. The hide is prepared in the usual way, and is then thrown into a strong lime for 8–10 hours, when it is taken out and immersed in water heated up to 43° (110° F.), in which it remains 24–48 hours. The warm water soaks, softens, and swells the roots of the hair, and much the same result is obtained as in "scalding" pigs. So little lime really permeates the inner fibre that, after a slight wheeling, the hides may be thrown into cold water, and allowed to cool and plump, preparatory to taking their places in the handlers. The process is strongly recommended for sole-leather, particularly where great firmness of fibre is desired. The tanner who tries it must be satisfied if he gets 20–30 sides a man unhaired and fully ready for the liquor per diem.

On the Continent and in America, the prevalent mode of loosening the hair, at least for sole-leather purposes, is called "sweating," and consists in inducing an incipient putrefaction, which attacks the soft parts of the epidermis and root-sheaths, before materially injuring the hide-substance proper. The old European method of "warm-sweating" consisted simply in laying the hides in pile, and, if necessary, in supplying heat by covering them with fermenting tan; but as this crude and dangerous process is everywhere being supplanted by the American plan, where sweating at all is adhered to, it is not necessary to do more than describe the latter. This is called "cold sweating," but really consists in hanging the hides in a moist chamber, kept at a uniform temperature of 15°–21° (60°–70° F.).

The "sweating-pit" now in use is sometimes of wood, but usually consists of a building of brick or stone, protected from changes of temperature, both above and at the sides, by thick banks of soil or spent tan. If soil be used, it will form an excellent bed for vines, &c., which are fertilized by the ammonia penetrating from below. Though called a "pit," it is undesirable that it should be actually below the level of the ground; it should be arranged so that the hides can be wheeled in and out in barrows. It is lighted and ventilated by a lantern roof above a central passage, and should be divided into chambers, each capable of suspending a pack of hides. By means of sprinklers above and steam-pipes below, the chambers may be cooled or warmed, as required, and when working properly, the temperature should stand at 15°–21° (60°–70° F.), with globules of condensed water collecting on all parts of the suspended hides.

The process is principally used in America for dried hides, but may be employed either for wet or dry salted, after complete removal of the salt. It is imperatively necessary that dried hides should be completely softened before sweating. As the sweating process advances more rapidly in the upper than in the lower part of the pit, and as the thick portions are more resistant than the thin ones, the hides, after about 3 days' sweating, require constant attention in changing their positions, and in checking the forward ones by taking down and laying in piles on the bottom of the pit.

The usual treatment for sweated hides, when the hair is sufficiently loosened, is to throw them into the stocks, and work out in this way the slime and most of the hair. This has the disadvantage of working out too much of the dissolved gelatine, and of fulling the hair so firmly into the flesh, that it is difficult again to remove it. To overcome these evils, some American tanners now pass the hides, after sweating, through a weak lime. This, to a great extent, prevents the hair fixing itself in the flesh, and tends to counteract the injurious effect of the vitriol (which is almost invariably used in plumping sweat stock) on the colour of the leather. By this process, 10,000 Texas and New Orleans wet-salted hides gave an average yield of leather of 73 per cent. on their green weight, and the leather was excellent in quality.

It must be clearly understood that all sweating depends on partial putrefaction. This is proved both by the plentiful production of ammonia in the pits, and by the fact that all antiseptics, such as salt or carbolic acid, entirely prevent sweating till they are removed. Although the process undoubtedly has advantages, and especially so in the treatment of dried hides, it is an open question whether it gives the extreme gains over limeing in weight and firmness, which are claimed by some of its advocates.

An unhairing process, largely coming into use on the Continent, depends on the action of alkaline sulphides, and particularly sulphide of sodium, upon the hair. While all the methods already spoken of involve the softening and destruction of the hair-sheaths, either by lime or by putrefaction, the sulphides are peculiar in attacking the hair itself; when strong, they disintegrate it rapidly and completely into a sort of paste. From very early times, sulphide of arsenic ("rusma") mixed with lime has been used in unhairing skins. About 1840, Böttger concluded that the efficacy of arsenic sulphide was due simply to the sulphydrate of lime formed by combination of the sulphur with the lime, and proposed sulphydrate of lime, formed by passing sulphuretted hydrogen into milk of lime, as a substitute for the poisonous and expensive arsenic compound. This proved a most effective depilatory, but has never obtained much hold in practice. This is probably due to the fact that it will not keep, oxidizing rapidly on exposure to the air; hence it must be prepared as it is required, which is both troublesome and expensive. A minor objection is the unpleasant smell of sulphuretted hydrogen, which is inseparable from its use.

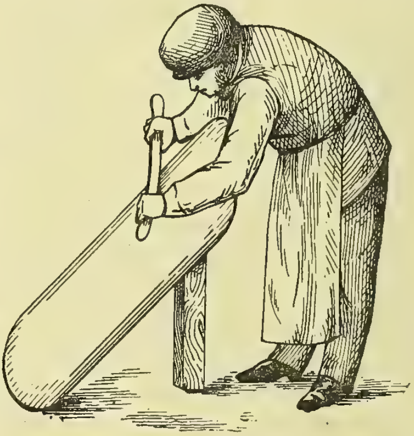
It was proposed to replace it by sulphide of sodium, which, though at first said to be only effective when mixed with lime, so as to produce calcic sulphide, has since proved a powerful depilatory alone. Its use has been greatly extended on the one hand by its production on a large scale, and in the crystallized form (presumably by reduction of sulphate by heating with small coal), and on the other, by the great interest which Wilhelm Eitner, the able director of the Austrian Imperial Research Station for the Leather Trades, has taken in its introduction. The substance, as manufactured by De Haen, of List, Hanover, is in small crystals, coloured deep greenish-black, by sulphide of iron, which must have been held in suspension at the time of crystallization. If the salt be dissolved in water, and the solution be allowed to stand, this is gradually deposited as a black sediment, leaving the supernatant liquor perfectly clear and colourless.

For sole-leather, the method recommended by Eitner is to dissolve 4–5 lb. of sulphide per gal. of water, making the solution into a thin paste (of soupy consistence) with lime or pipe-clay. This is spread liberally on the hair side of the hides, one man pouring it down the middle of the hide from a pail, while another, with a mop or cane-broom, rubs it into every part. The hide is then folded into a cushion, and in 15–20 hours will be ready for unhairing, the hair being reduced to a paste. In the writer's experience, the concentrated solution here prescribed will completely destroy all hair wetted with it in 2–3 hours, and if left on longer, will produce bluish patches, and render the grain very tender. The hides should be thrown into water before unhairing, to enable them to plump, and to wash off the sulphide, which is very caustic, attacking the skin and nails of the workmen. There is no doubt that this process gives good weight, and tough and solid leather; but there are several difficulties attending its use. Unless the mopping is done with great care, it will fail to completely destroy the hair, and the patches of short hair left are very difficult to remove. The expense of the material and the loss of hair are also important considerations. The hides will be very difficult to flesh, unless previously plumped by a light limeing, and it is generally considered necessary to swell the hides with acid before tanning, as the sulphide has but little plumping effect.

Another method, which is more generally adopted for dressing hides, is to suspend in a solution of sulphide of sodium, containing about ¾ lb. a hide; the hide is said to unhair in 24 hours. Very weak solutions loosen the hair, without destroying it; but it is always injured, as the specific action of the sulphides is on the hair itself. After unhairing, the hides may receive a light limeing, to plump them, or lime may be added to the solution of sulphide.

Various other depilatories have been proposed, but as they have not come into general use, brief mention of the most important will suffice. Anderson, in 1871, patented the use of wood-charcoal, applied in a similar manner to lime in the ordinary process. The hair was probably loosened simply by putrefaction, as in sweating, while the charcoal acted as a deodorizer. Caustic potash and soda will loosen hair, but seem to have no decided advantage over lime. They are more costly, and their corroding action on the hide-substance is more powerful. Squire, Claus, and J. Palmer, have all taken out patents for the use of tank-waste as a depilatory. It consists of impure sulphides of calcium, and when brought into the form of soluble sulphydrate, either by boiling in water, or, it is said, by the oxidizing action of the air, it will unhair hides. The conversion is, however, very imperfect in either case, and its action is uncertain and slow; while the iron present is apt to cause unsightly stains. It is probable that the weights obtained may somewhat exceed those by limeing. Palmer employs sulphuric acid to plump the hide and remove stains, and then reduces it by a bate of whiting and water. He claims that this prepares the hide for rapid and heavy tanning, but the swelling and subsequent reduction almost certainly entail loss of weight and quality.

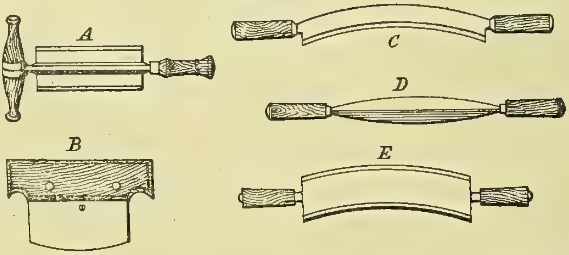
902.



Whatever method of loosening the hair may be adopted, the next step is to remove it by mechanical means. This is usually accomplished by throwing the hide over a sloping beam, and scraping it with a blunt two-handled knife (Fig. 902), the workman pushing the hair downwards and away from him. The beam is now usually made of metal. The knife employed is also shown at C, Fig. 903.

When a hide is lightly limed, it is often easy to remove the long hair, but excessively difficult to get rid of the short under-coat of young hairs, which are found in spring, and which can sometimes only be removed by the dangerous expedient of shaving with a sharp knife. The reason of this difficulty is obvious: not only do the short hairs offer very little hold to the unhairing knife, but, as has been explained in describing the anatomical structure of the skin, their roots are actually deeper seated than those of the old hairs they replace. Several attempts have been made to unhair by machinery, but so far without such success as to lead to their general adoption. The fleshing-machine invented by Garric and Terson, and manufacured in this country by T. Haley and Co., of Bramley (Fig. 904), is furnished with a special wheel for unhairing. An American machine for the purpose, invented by J. W. Macdonald, and said to be capable of unhairing 800 sides a day, is shown in Fig. 905.

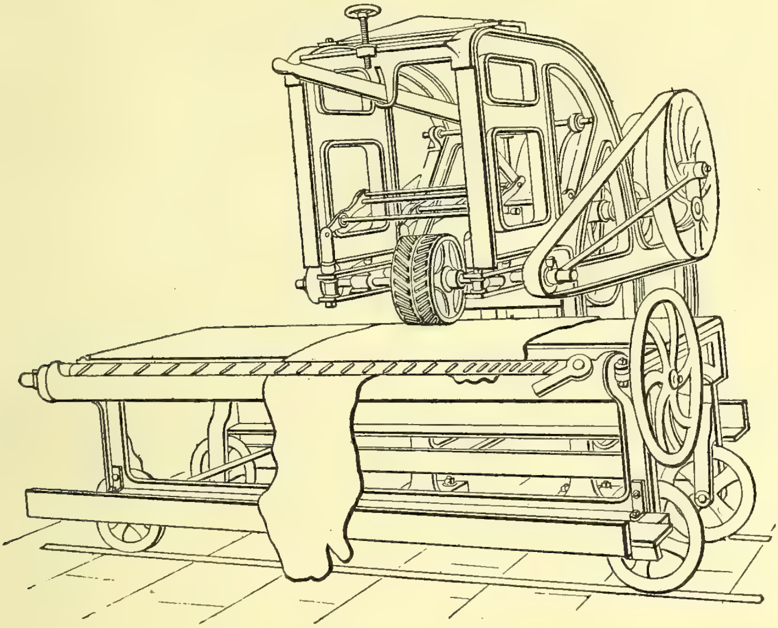
903.



When the hair is very thoroughly loosened, as by sweating, or destroyed, as by sulphide of sodium, it is not uncommon to work it off by friction in the stocks; but it is very doubtful whether the saving of labour is not more than compensated by the loss of weight, consequent upon submitting the hide, while its gelatine is in a partially dissolved condition, to such rough usage.

After unhairing, the loose flesh and fat are removed from the inner side of the hide by a sharp-edged knife E (Fig. 903), partly by brushing or scraping, partly by paring. It is necessary not only to cut off the visible adhering fat, but to work the hide well, so as to force out that contained in the loose areolar tissue, which would not only impede tanning, but is liable to soak completely through the hide, producing most unsightly blotches. Several machines have been introduced to supersede hand-fleshing, but with only partial success. One of the best is Garric and Terson's machine (Fig. 904), which gives a very level flesh, free from galls, and without so much loss of weight, but scarcely so clean as desirable, while the saving in labour is not great. Molinier's machine (Fig. 906), and that of Jones and Rocke, are well adapted for skins, but hardly capable of fleshing an entire hide. All these machines are very similar in principle, the working parts consisting of drums with oblique or spiral knives.

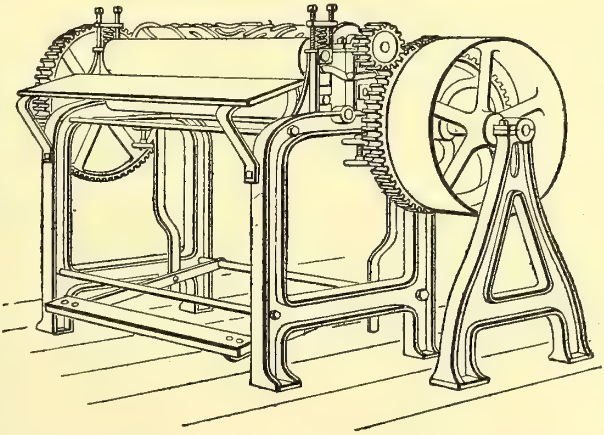
904.



When unhaired and fleshed, the hides intended for sole-leather, are, in England, almost invariably "rounded," or separated into (1) "butts," which are the best and thickest parts, and receive the most solid tannage, and (2) "offal," which is thinner, and for which a cheaper and more rapid tannage is sufficient. Fig. 907 shows the customary division. Frequently the butt is divided down the centre, and the halves are then called "bends." A piece called a "middle" is sometimes taken between the butt and the shoulder.

After rounding, it is necessary to get rid of the lime, as completely as possible, before taking into the tan-house. For this purpose, the butts are usually suspended in fresh water for 12–24 hours, and frequently shaken up in it to remove adhering lime and dirt. If the water is hard, it is best to add to it, before putting in the butts, a few pailsful of clear lime-water, to precipitate the acid carbonate of lime, which would otherwise cause a deposit of chalk on the surface of the butts; this would not only make the grain harsh, but afterwards, by combining with the tannin of the liquors, would cause bad colour. For the same reasons,

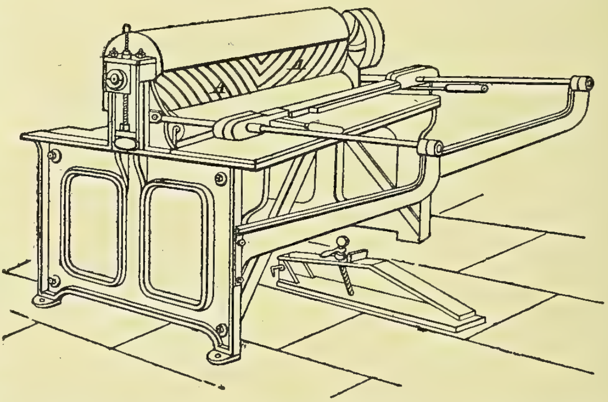
905.



it is important that limey hides should be as little exposed to the air as possible, as the latter always contains a small amount of carbonic acid, which renders the lime insoluble.

This suspension in water is generally considered sufficient for sole-leather, but it removes the lime very imperfectly. In olden days, it was customary not only to wash the hides much more thoroughly in water, but to "scud" them (i. e. work them over with a blunt knife), to remove lime, and the detritus of hair-roots and fat-glands. This is now frequently omitted from sole-leather treatment, but no doubt leads to a more complete removal of the lime.

906.

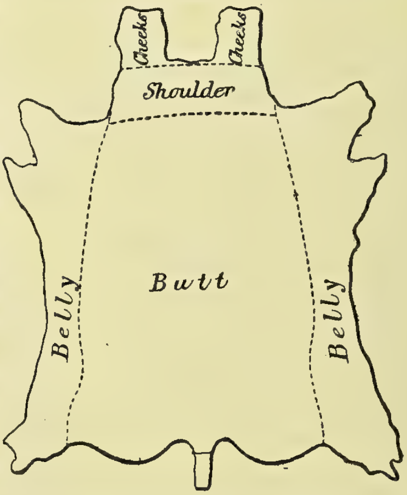


Tanning Materials. — Before describing the management of the hides in the tan-house, it is necessary to say a few words about one or two of the principal materials used, and the methods of preparing them. Further details of their nature and origin will be given in the article on Tannin.

Oak-bark is one of the oldest of tanning materials, and the leather produced by its aid is still considered for many purposes the best. For sole-leather, its weakness in tannin (8–12 per cent.), the slowness of its action, and the light weight of the leather produced, render it unavailable alone except for the very finest class of work. It is, however, generally used in admixture with stronger and cheaper materials, such as valonia.

Valonia, the acorn-cup of an evergreen oak growing in Greece and the Levant, is perhaps the most important of materials to the sole-leather tanner. It contains 25–35 per cent. of a tannin somewhat similar to oak-bark, and, like it, communicating a light-coloured bloom to the leather, but giving much greater firmness and weight, and a browner colour.

907.



Myrabolanes or myrobalams, the fruit of an Indian shrub, contains about as large a percentage of tannin as valonia, and gives a similar bloom, and excellent colour; but it can only be used very sparingly on butts, since it produces a soft and porous leather.

Divi-divi is a S. American bean, which contains much of a brown tannin in the pod, being considerably stronger than valonia. It makes a heavy and solid but somewhat horny leather. Its great danger arises from a tendency to sudden fermentation, which produces brown or red stains on the leather.

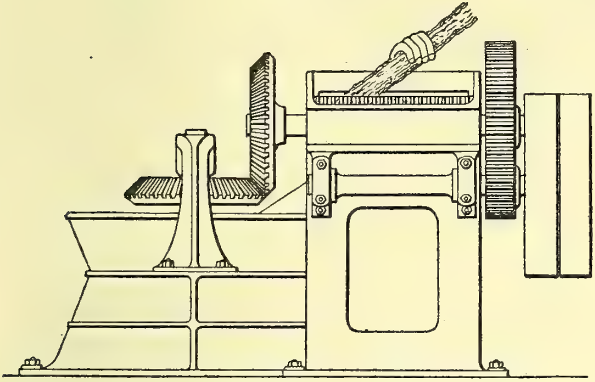
Mimosa-bark is the product of several Australian acacias, and is probably nearly as strong as valonia. It gives a hard and heavy leather, but of a dark-red colour.

Hemlock-extract is a deep-red syrupy extract of the bark of the hemlock pine of America.

Chestnut-extract is a similar product from the rasped wood of the Spanish chestnut. Its colour is paler and yellower than that of the hemlock, and hence it is often employed to correct the red tone produced by the latter.

Grinding and Exhaustion of Tanning Materials.—Before tanning materials can be exhausted, it is almost invariably necessary to crush or grind them, so as to enable the water to get freely at the tannin, which, in most cases, is enclosed in the cellular tissue of the plant. It may be thought that for this purpose it would scarcely be possible to crush too finely, but in practice, a very fine powder is extremely difficult to spend, as it cakes into compact and clay-like masses, through which liquor will not percolate. The object, therefore, is to grind finely enough to allow the liquor ready access to the interior, but not so finely as to prevent liquids running through the mass. The mill most usually employed for this purpose consists of a toothed cone, working inside another cone, also toothed on its interior, precisely like those of a coffee-mill. As bark is frequently delivered "unhatched," or in long pieces, it is necessary to crush it preparatory to grinding, and this is usually accomplished by rollers composed of toothed discs, called breakers. In Fig. 908 is illustrated such a mill, as made by Newall and Barker, of Warrington, combining both utensils. Fig. 909 shows a section of the well-known American "keystone" mill, in which the preliminary breaking is accomplished by the arms A; the bark is then finely ground by the toothed cones N, and discharged at the spout R by the revolving shover M.

908.



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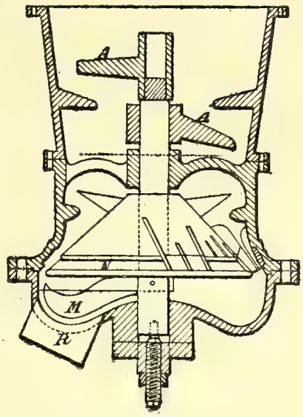
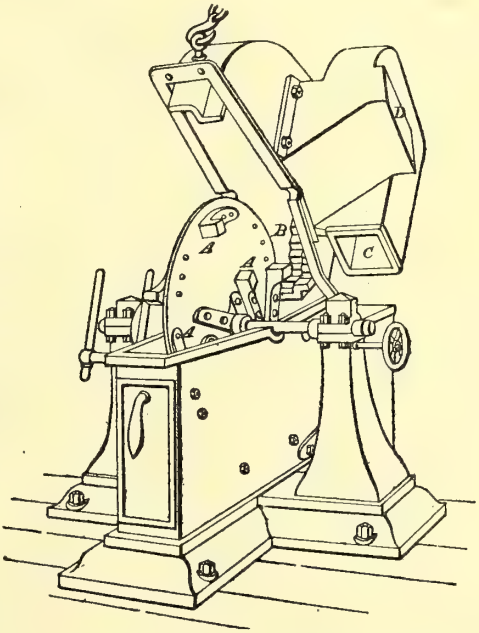


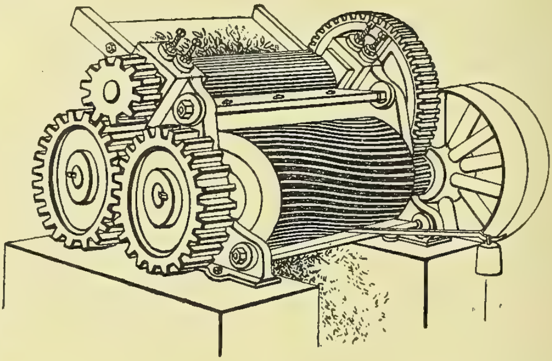
Now that a large variety of other materials besides bark are required by tanners, the mill just described is not always sufficient for the purpose. Myrobalams and mimosa-bark have proved specially troublesome, the former from its very hard stones and clogging character, and the latter from its combined hardness and toughness. "Disintegrators" of various makes have proved admirably adapted for grinding both of these materials, their advantage being the universality of their reducing powers, ranging from oak-bark to bones or brick-dust, and their disadvantages, the somewhat considerable power they consume, and the rather large portion of fine dust they make. Their principle is that of knocking the material to powder by rapidly revolving beaters, which, in the smaller mills, are driven at so high a speed as 2500 rev. a minute. Wilson's is shown in Fig. 910, as an example. It is one of the oldest tanners' disintegrators, and probably still one of the best. In the figure, it is opened, showing the disc with its steel beaters attached. When myrobalams are only required roughly crushed, a machine with fluted rollers (Fig. 911) acts better than a disintegrator, making less dust, and requiring less power.

910.



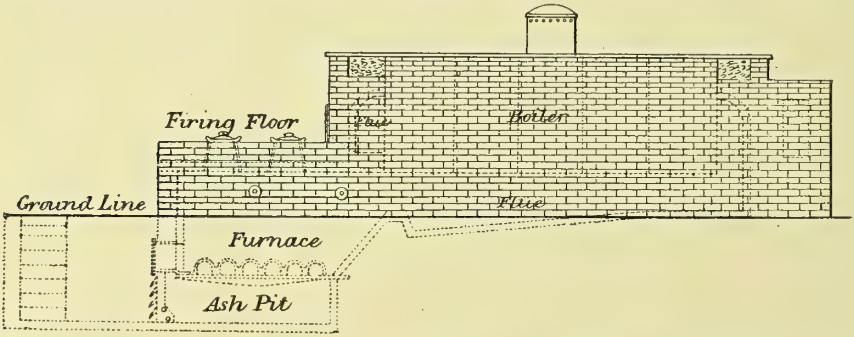
In England, the tanning material is generally carried from the mill, to the pits where it is exhausted, in baskets or barrows; in America, this is frequently accomplished by a "conductor," or horizontal spout, in which a double belt with wooden cross-pieces carries the bark forward, on the same principle as the elevators of corn-mills. Another American plan is to use circular tubs for extraction. These are mounted on wheels, and are worked on a railway, coming up to the mill to be filled, and thence under a series of sprinklers like those used by brewers, and finally "dumping" their contents before the boilers, which are heated solely by the wet bark, burnt in a peculiar furnace with brick chambers. This furnace for burning wet bark seems worthy of extended adoption in Europe, as spent tan is frequently not only valueless, but costly to get rid of. Full details and scale drawings may be found in Jackson S. Schultz's book on 'Leather Manufacture,' and in Fig. 912, is shown a modification of it, patented by Huxham and Brown, which has been very successfully used in burning wet tan, either alone or with a portion of coal. In American sole-leather tanneries, where the bark is resinous and almost unlimited in quantity, sufficient steam may be raised with tan wet from the lecks; but in England, where material is more sparingly used, it is advisable partially to dry it before burning. This is accomplished by powerful roller-presses, as shown in Fig. 913.

911.



In England, the tanning material is usually exhausted in pits called "lecks," "latches," or "taps." These, in large yards, are made capable of holding about 50 cwt. of material. The new material is first flooded with a pretty strong liquor. When this has gained as much strength as possible, it is pumped off, and is followed by a weaker one, and so on till the material is exhausted. Much of the economy of a tan-yard depends on the way, systematic or otherwise, in which this is done. It is customary to complete the exhaustion with hot liquors, or water, but opinions differ on the expediency of the practice. By the use of heat, however, stronger liquors and more rapid spending are attained; and with some materials, such as mimosa, complete exhaustion is impossible in the cold. Careful tanners also cast their material over from one pit into another, before throwing away, so as to lighten it up, and allow the liquor to penetrate to every part. In bark-yards, latches are frequently worked in series, which are connected by pipes, so that the liquor flows from the bottom of one upon the top of the next stronger. This is an excellent plan for bark, which is open and porous, but is scarcely adapted to such materials as valonia or myrabolams, which have a tendency to form compact masses, through which the liquor does not circulate. The same objection, in an almost higher degree, must be urged against the Allen and Warren, or sprinkler leck, in which the liquor, distributed on the surface by a rotary sprinkler, is allowed to percolate downwards, and run freely away at the bottom. In this case, it is almost sure to form channels, instead of flowing uniformly, and, in addition, the material is constantly exposed to the action of the air, which causes fermentation, with its attendant discoloration and loss of tannin.

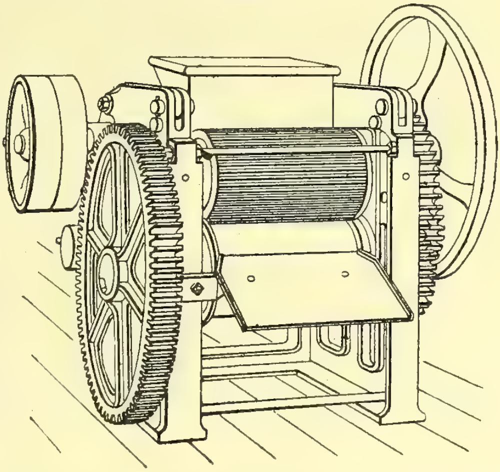
912.



It is one of the great attractions of extracts that they avoid almost all the expense and labour inseparable from the exhaustion of other tanning materials. It is usually necessary to dissolve the fluid extracts in water or liquor of as high a temperature as has been employed in their preparation, as otherwise, from some unexplained chemical change, a large portion of the tannin is precipitated. Gambier is usually dissolved by boiling or steaming, but is said to give a better colour when dissolved cold. This may be accomplished in a rotating latticed drum, sunk in a pit of liquor.

Construction of Tanneries.—The old-fashioned method of sinking pits is to make them of wood, and carefully puddle them round with clay, which should be well worked up before use. Loam mixed with water to the consistence of thin mortar may also be employed, the pits being filled up with water, to keep them steady, at the same rate as the loam is run in. Probably the best materials for pit-sides are the large Yorkshire flagstones. Where these are not attainable, very durable pits may be made of brick, either built with Lias lime, and pointed with Portland cement, or built entirely with the latter. Common lime cannot be used, as it spoils both liquors and leather; and even cements with too large a percentage of lime are unsatisfactory. Brick and common mortar are, however, suitable for lime-pits. If possible, both latches and handler-pits should be provided with plugs and underground pipes, communicating with a liquor-well some feet below their levels. Glazed fireclay is very suitable both for pipes and plug-holes, which should be in the pit-corners. Iron should, as far as possible, be avoided wherever it can come into contact with liquor, as it discolours the leather.

913.



Management of Sole-leather in the Tan-house.—After suspension in water, the hides are usually taken at once into weak tan-liquors; but occasionally they are treated with dilute acids before the actual tanning, both to remove the lime still remaining in the pelt, and to plump them. If the sole object be the former, hydrochloric acid is probably the most suitable, since the calcic chloride formed is very soluble, and, in small quantities, hydrochloric acid has not the bad effect, often produced by sulphuric, of causing a dark layer to form immediately beneath the grain during tanning. If acid is to be used for plumping, it is, no doubt, best to use it mixed with the early liquors, where its influence is modified and restrained by the tannin; but it seems probable that, where lime is used for unhairing, the fibre is sufficiently opened up by this agent to receive the tanning, and that, in a well-managed yard, the natural acids of the liquors are sufficient, in conjunction with suitable tanning materials, to give the hides all the weight and substance of which they are capable.

On first coming into the yard, the butts are usually suspended by the necks from sticks placed across the pits. They should be kept in almost constant movement, either by raising and shaking them by hand, or by supporting them on frames, which are rocked, or otherwise worked. Perhaps the best device for this purpose is the "travelling handler" of W. N. Evans, which consists of a frame supported on wheels, and worked slowly backwards and forwards by power. This frame should extend the length of a range of pits sufficient to take in at least a 3 days' stock of butts, which should be tied by the neck end to sticks resting crossways upon it. It should have a stroke of 1–2 ft., repeated, say 6 times a minute.

The suspender pits should be supplied with old handler liquors, which, if the tannage is a mixed one, may range from 12°–16° barkometer, as a large proportion of the weight consists only of lime-salts, gallic acid, and other worthless products. If the tannage is pure bark, it may perhaps be advisable to let the strength be somewhat less, but something depends on whether the exhausted liquors are returned with all their impurities to the "taps" or liquor-brewing pits, or whether the liquors are made with water, and hence purer. In any case, the free acid in the suspenders should always be sufficient in quantity to neutralize the lime brought in by the butts, or bad colour will certainly result, making itself visible in the shed, or as the tanning proceeds. If the butts, when first brought into liquor, take a lemon-yellow colour, especially in places that have been imperfectly exposed to it, this is an indication of danger which must not be disregarded. It may be met either by cleansing the butts more thoroughly before bringing into the yard, or by adding acid (acetic, hydrochloric, or sulphuric) to the liquor. It can, however, often be remedied, either by altering the way of working the liquors, so as to bring more sour liquor down to the suspenders, or by using a larger proportion of materials capable of yielding acetic acid by fermentation, such as myrobalams. It is a common error to call all the free acid of sour liquors "gallic," as this is not even present in pure bark-yards, and at the best is a feeble acid, scarcely reddening litmus, or capable of swelling hides. The most abundant acid is usually acetic, though butyric, lactic, and other acids are frequently present. It must here be explained that the barkometer (also called "barkrometer" or "barktrometer") is a hydrometer, graduated to show the sp. gr. thus—20° Bark. = 1·020 sp. gr.

The butts should at first be brought into the weakest liquor; a circulation system, by which the liquors are all pumped in at one end of a set of suspenders, and run out at the other, the butts being moved forward in the opposite direction, seems to have much to recommend it. In this case, the top of one pit should be connected by a wooden box with the bottom of the next.

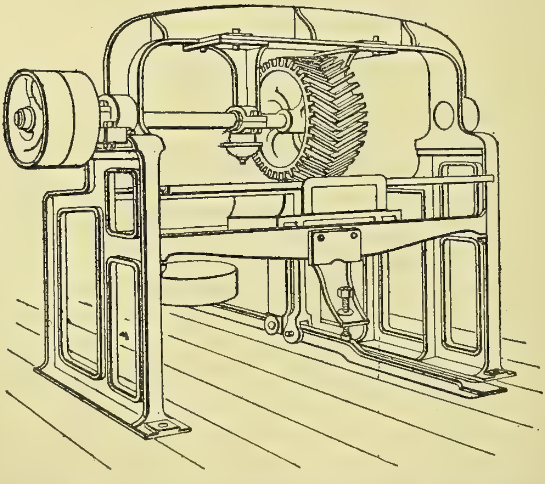
It is usually advisable to run away the first liquor into which butts are brought from the lime-yard, as it is very completely spent, and highly charged with lime salts and impurities. Whether other exhausted liquors are to be retained or rejected is largely a question of climate, and mode of working. In hot weather, such liquors, charged with organized ferments (moulds, *bacillus*, and *bacteria*), are apt to cause ropiness, and other fermentive diseases of the liquors. This danger may be lessened by boiling all spent liquors, so as to kill the ferments, before running on the taps, or prevented by the free use of antiseptics, such as carbolic acid. Small doses of carbolic acid, however, are useless; at least $\frac{1}{10}$ per cent. must be employed.

The suspender liquors should be acid enough freely to redden litmus-paper. H. R. Procter has published a simple and instructive volumetric method for the determination of the free acid: 10 cc. of the carefully filtered liquor is placed in a beaker, and clear lime-water is run in from a burette till permanent cloudiness is produced. The quantity of lime-water employed is that which the acid is capable of neutralizing, without producing discoloration of the leather, and care must be taken that the lime introduced with the butts does not exceed this proportion. The explanation of the reaction is that dark-coloured tannates of lime are formed, which are dissolved by the free acid so long as it remains in excess.

From the suspenders, the butts are transferred to the "handlers," where they are laid flat in the liquor. The handlers are generally worked in sets, to each of which a fresh liquor is daily run, and the most forward pack is pulled over into it, and is often also dusted down with a little fine bark or myrabolams. The second pack follows into the liquor out of which the first has been taken; the third into that of the second, and so on. Frequently the greenest packs are handled up a second time in the course of the day, and put down again in the same liquor. The strength of liquors, and the length of time for which butts are retained in the handlers, are varied; but a time of 1–2 months, and liquors of 20°–35° are usual. A little gambier may be appropriately used in the liquors.

At the end of this period, the butts are taken to the "layers" or bloomers, in which they are laid down with stronger liquors and much larger quantities of "dust"; the latter is usually bark or valonia, though mimosa is occasionally used. The liquors vary from 40°–60° or 70° in strength in mixed tannage, and the duration of each layer from 10 days in the earlier stages to a month in the later ones. For the best heavy tannages, 6–8 layers are required. Each time the butts are raised, they should be mopped on the grain, to remove dirt and loose bloom. In pure bark tannage, which, however, is gradually becoming extinct, the liquors used are of necessity much weaker, as it is extremely difficult to obtain liquors of more than 25°–30° from this material. The last layer, however, should always have liquors of the greatest strength which can possibly be obtained, or the leather will be deficient in firmness.

914.

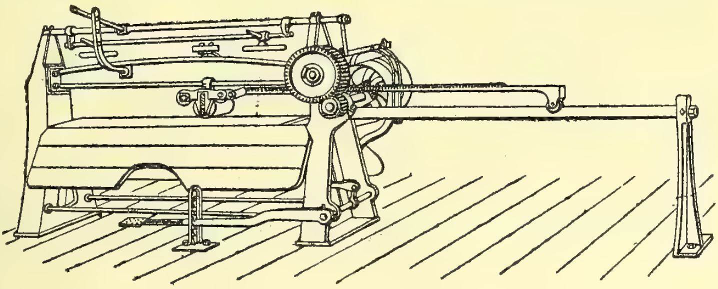


The great point to aim at, in arranging the mode of work of a tannery, is to contrive that butts should always receive the strongest liquors they can bear with safety, and that the strength should constantly increase in a regular and systematic way. To attain this end, very frequent handling and change of liquor are requisite in the early stages, when the butts rapidly absorb the tannin presented to them. As the process advances, the exterior part of the butt becomes thoroughly tanned, and the liquor only slowly reaches the interior, which is yet susceptible of its action, and hence longer layers in stronger liquors are permissible.

The varied requirements of the trade render it difficult to give any practical information as to selection of tanning materials. As a general rule, it is important at the outset to give the required colour; and if materials undesirable in this respect are to be used for the sake of cheapness, they should be introduced in the form of liquors in the middle stages of the process, i.e. in the later handlers or earlier layers. Materials used as dust generally have more effect in producing bloom and colouring the leather, than those used in liquors at this stage. Some information as to the respective qualities of the different tanning materials will be found in the article on Tannin; but even practical men are very deficient in accurate information on these points, since many materials are never used alone, but invariably in connection with others which mask their effects.

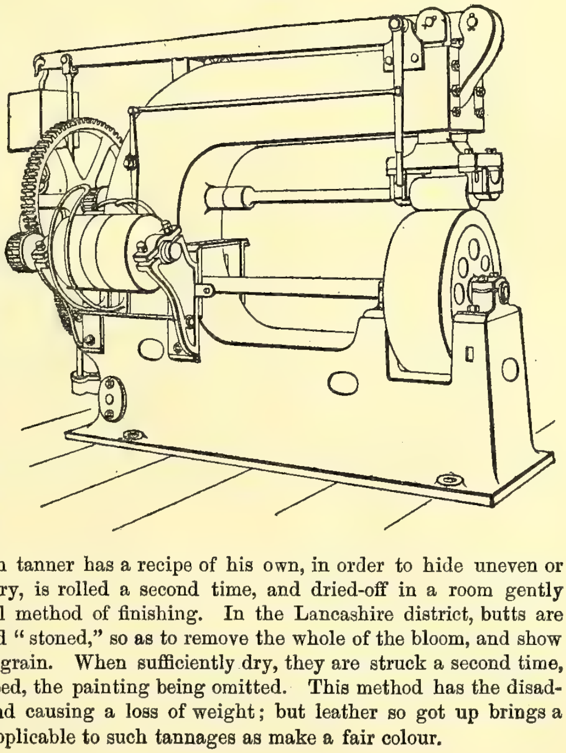
The use of extracts, and the demand for low-priced leathers, to compete with the American tannages, has introduced still more rapid methods than those described, and very fair-looking heavy leather has been tanned in 5–10 weeks. These tannages are very various, but their main feature is the free use of hot liquors, composed principally of extracts and gambier. This treatment imparts great firmness, or more properly speaking, hardness; but the leather is deficient in toughness, and the grain usually cracks on bending sharply. Extract properly used is, however, capable of making excellent leather.

915.



Treatment of Sole-leather in the Shed.—The butts, after being well mopped on both flesh and grain in a clear liquor, are taken into the drying-lofts, where they are hung on poles till about half dry. They are then laid on the floor in piles, and covered up till they heat or "sweat" a little, which facilitates the succeeding operation of "striking." This is performed by laying the butt over a horizontal "beam" or "horse," and scraping its surface with a triangular pin, shown at D in Fig. 903. This pin has an even, though tolerably sharp, edge, and is so used that it stretches and smooths out the grain, without breaking it; at the same time, it removes a portion of the white deposit called "bloom," which has been mentioned. Common goods are frequently struck by the machine introduced by Priestman, of Preston Brook, shown in Fig. 914; but the work is not very uniform, and the leather is much compressed and stretched. After a light oiling and a little further drying, the butt is laid on a flat "bed" of wood or zinc, and is rolled with a brass roller loaded with heavy weights. Various machines are also in use for this purpose. In Fig. 915, is shown a roller adapted for rolling butts, in which the pressure is produced by springs immediately above the roller, which works backward and forward over a flat table. Fig. 916 represents a machine in which the roller is fixed, and works over a brass drum; it is specially adapted for offal, and, when used for butts, is apt to make them "baggy." In both these machines, the reversing motion is obtained by using two belts, one being crossed. The leather is now frequently coloured on the grain with a mixture, for which each tanner has a recipe of his own, in order to hide uneven or dull colour, and, when sufficiently dry, is rolled a second time, and dried-off in a room gently heated by steam. This is the Bristol method of finishing. In the Lancashire district, butts are generally struck out much wetter, and "stoned," so as to remove the whole of the bloom, and show the natural brown "bottom" of the grain. When sufficiently dry, they are struck a second time, to set the grain, and rolled as described, the painting being omitted. This method has the disadvantage of requiring more labour, and causing a loss of weight; but leather so got up brings a higher price, as the method is only applicable to such tannages as make a fair colour.

916.

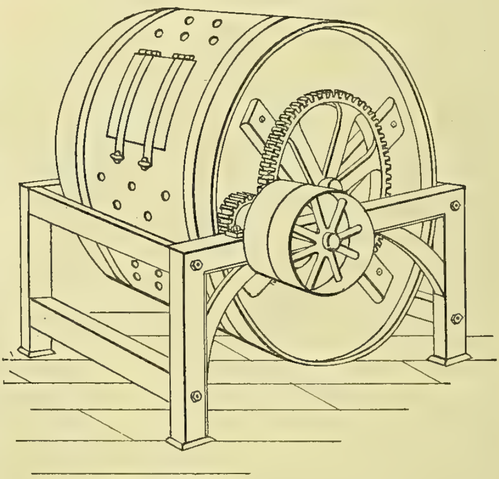


It is very important, and especially so with heavy mixed tannages, that the drying should be conducted in the dark, and not too rapidly. No artificial heat should be used, except in frosty weather, to wet leather ; and it should be carefully protected from harsh drying winds. After the leather is finished, it should be dried-off in a well-ventilated drying-shed, heated to about 21° (70° F.). The same observations apply to the drying of rough dressing-leather, except that artificial heat should be avoided. Frost makes dressing-leather porous, and prevents its carrying a proper quantity of grease in currying.

Tannage of Dressing-leather. Common, and Shaved Hides.—Hides which are intended for purposes where softness and flexibility are required, as for instance, for the upper-leathers of boots, and for saddlery purposes, are called "dressing" or "common" hides, or, if they are shaved down to reduce their thickness before tanning, they are denominated "shaved" hides. Hides for this purpose are limed much in the same way as has been described for butts ; but if they are required very soft and flexible, a somewhat longer limeing is permissible. After unhairing, fleshing, and washing in water, they are usually transferred to a "bate," composed of pigeon- or hen-dung, in the proportion of about 1 peck to 25–30 hides.

In this they are retained for some days, being handled frequently. They completely lose their plumpness, and become soft and slippery ; the caustic lime is entirely removed ; and the remaining portions of hair-sheaths and fat-glands are so loosened that they are easily worked out by a blunt knife on the beam. This final cleansing process is called "scudding." The theory of the action of the "bate," or "pure," as it is sometimes called, is somewhat imperfect. It is frequently attributed to the action of ammonia salts, and phosphates, contained in the fermenting dung. Ammonia salts certainly will remove caustic lime, but, in this case, free ammonia is liberated in its place, which is just as powerful in swelling the pelt, and hence will not account for the rapid reducing effect ; while the phosphates of dung are mostly, if not entirely, in the form of phosphate of lime, which is quite inert. In point of fact, the process seems to be a fermentive one, the active bate swarming with *bacteria ;* to this, rather than to its chemical constituents, its action must be attributed. The *bacteria* act not only on the organic constituents of the dung, but on those of the hide, producing sulphuretted hydrogen, together with tyrosine and leucine, and other weak organic acids, which neutralize and remove the lime, and, at the same time, soften the hide by dissolving out the coriin, and probably also portions of the gelatinous fibre. The truth of this theory is supported by the fact that, in warm weather, the activity of the bate is greatly increased, and that, if one pack of hides is over-bated, the next following is much more severely affected, the hides having in fact themselves furnished food for the multiplication of the bacterian ferment from the destruction of their own tissues. It also explains the effective use (as a substitute) of warm water with a very small portion of glucose, which, in itself, would be insufficient to dissolve the lime, but with a small quantity of nitrogenous matter, forms an excellent *nidus* for the multiplication of these organisms. In this connection, may be mentioned the fact that, when bran drenches are used, in which lactic acid is developed, the butyric fermentation is liable, in hot weather, to take its place, and as butyric acid is a powerful solvent of gelatinous tissue, and the dissolved tissue itself feeds the fermentation, rapid destruction of the skins is the result.

917.



If the removal of the lime be the only object aimed at in bating, the ordinary process is most wasteful, as well as disgusting, from the loss of pelt it entails. It is easy to find chemical reagents which will remove the lime ; but the resultant leather has been found wanting in softness, and it is probable that the solution of the intercellular matter is in many cases advantageous.

The bating required may, however, be shortened, and probably with advantage, by washing the hides with warm water in a "tumbler," or rotating drum, Fig. 917, prior to putting them into the bate, or the whole bating may be done in the tumbler. After a short bating, also, the hides may be softened and cleansed by stocking for 15–20 minutes.

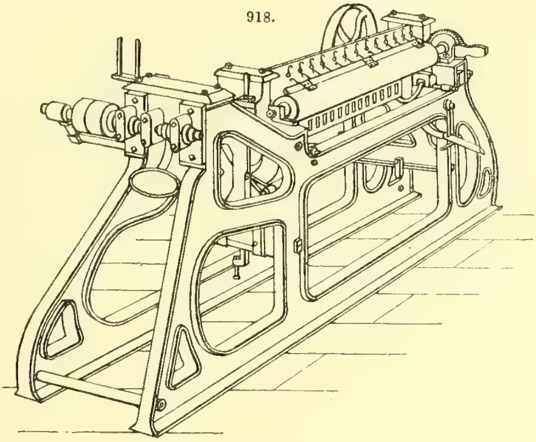
Various machines have been proposed to take the place of hand-labour in the beam work, and, at least as regards the smaller skins, with considerable success. As a type of these, may be mentioned

Molinier's hide-working machine, Fig. 906, which consists of a drum covered with helical knives, otating at a speed of about 500 rev. a minute, over a cylinder coated with indiarubber. The kin is allowed to be drawn in between these drums, and the two being pressed together by a treadle, t is drawn out by a mechanical arrangement in a direction contrary to the rotation of the knives, vhich scrape off the flesh, or work off the hair.

After bating, "shaved" hides are reduced in thickness in the stronger parts by a shaving-knife, n an almost perpendicular beam. The workman stands behind the beam, and works downwards. The knife is represented at A, Fig. 903, and is a somewhat peculiar instrument. The blade is of oftish steel, and after sharpening, the edge is turned completely over by pressure with a blunt ool, so as to cut at right angles to the blade. There is an obvious economy in shaving before anning, since the raw shavings are valuable for glue-making, while, if taken off by the currier, they re useless for this purpose. The hide also tans faster.

Instead of shaving, the untanned hide is frequently split, by drawing it against a rapidly ibrating knife. The piece removed is tanned for some inferior purpose, if sufficiently perfect. n sheep-skins, which are split by a pecial machine, the grain-side is tanned or French morocco or basil, while the lesh-side is dressed with oil, and forms he ordinary chamois or wash-leather. Such a machine is shown in Fig. 918.

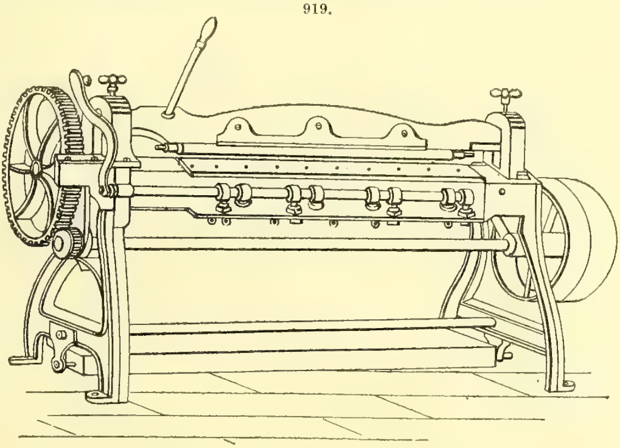
918.



Tanned leather is usually split by orcing it against a fixed knife, as in the merican "Union" machine, Fig. 919.

After bating, scudding, and shaving, he hides are taken into the tan-house, vhere they are grained, either by frequent handling, or by working in a addle-tumbler (a vat agitated with a addle-wheel), with a liquor of suitble strength. What this strength hould be depends on whether a wellnarked grain is required or not. The tronger the liquor, the more it con-racts the hide, wrinkling the surface into a network of numberless crossing furrows, which form the vell-known marking of "grain-leather." In bark tannage, the after management is much like that lescribed with sole-leather, except that weaker infusions are employed, and acid liquors, which vould swell the hide and produce a harsh leather, are avoided. In old-fashioned country yards, vhich produce some of the est bark-tanned shaved ides, the liquors rarely ange above 10°–15° of the arkometer, and the time mployed is 3–6 months. The ides, after passing through set of handlers, of gradu-lly increasing strength, in vhich they are at first moved very day, are laid away vith bark liquor and layers f fresh bark, receiving per-aps 4–5 layers of 2–4 weeks ach. Unfortunately, these annages are so unprofitable hat they are rapidly being upplanted by quicker and heaper methods.

919.



These more rapid and heap tannages mostly depend on the use of "terra" (block or cube gambier) in combination ith bark, valonia, or myrabolams. Liquors warmed to 43° or even 60° (110°–140° F.) are employed, nd a bright colour is finally imparted by handling in a warm sumach or myrabolams liquor, which issolves out much of the colour imparted by terra or extracts. The tannage is helped forward by requent handling, by working in tumblers, or sometimes by suspension on rocking or travelling rames, after the American fashion.

To this class of tannage belongs that of E. India kips, which is largely carried on in the neighbourhood of Leeds. These kips are the hides of the small cattle of India, and are imported in a dried condition, and with their flesh side protected (and loaded) with a coat of salt and whitewash or plaster. They are usually softened in putrid soaks, and unhaired with lime, and are used in England for many of the purposes for which calf-skins were formerly employed. A variety of E. India kips, called "arsenic kips," are treated (instead of plastering) with a small quantity of arsenic before drying, to prevent the ravages of insects, which are often very destructive to these goods. Many kips tanned in India have also been imported of late years, and have greatly interfered with the profits of English tanners.

Drying Upper Leathers.—In yards where the leather is intended to be sold uncurried, it is taken up into the drying-sheds, well oiled on the grain with cod-liver oil, and either simply hung on the poles to dry, or stretched with a "righter," a tool shaped somewhat like a spade-handle, and finally set out with it to a smooth and rounded form. It is, however, now very common for the tanner who produces such leather also to curry it, and, as this effects a considerable economy, both in labour and material, it is likely to become universal. When leather is to be sold rough, it is necessary to tan it in such a way as to give it a white appearance, from the deposit of "bloom" already mentioned, this being regarded by curriers as an essential mark of a good tannage, although the first step in the currying process is to completely scour it out. When the tanner curries his own leather, he of course aims at putting in as little bloom as possible, thus saving both tanning material and labour. In addition, the leather goes direct from the tan-house to the currying-shops, thus saving both drying and soaking again, and, it is said, gives better weight and quality. The tanner, too, is enabled to shave his hides or skins more completely, utilizing the material for glue-stuff, which, had the leather been for sale in the rough, must have been left on to obtain a profitable weight.

Currying.—In general terms, the process of currying consists in softening, levelling, and stretching the hides and skins which are required for the upper-leathers of boots, and other purposes demanding flexibility and softness, and in saturating or "stuffing" them with fatty matters, not only in order to soften them, but to make them watertight, and to give them an attractive appearance.

It is obvious that great differences must be made in the currying process, according to the character of the skin and the purpose for which it is intended, since the preparation of French calf for a light boot, and of the heaviest leather for machine belting, equally lie within the domain of currying. In this case, however, as in that of tanning, the clearest idea of the general principles involved will be gained by taking a typical case, and afterwards pointing out the different modifications needed for other varieties. The French method of currying waxed calf is selected as an example, since the well-known excellence of this leather makes it interesting to compare the details with the methods ordinarily in use in this country.

After raising the skins from the pits, and beating off the loose tan, they are hung in the sheds till partially dry (*essorage*), great care being taken that the drying is uniform over the whole skin. In modern shops, this drying is usually accomplished at once, and in a very satisfactory manner, by means of a hydraulic press. If dried in the air, they must be laid in pile for a short time to equalize the moisture, and then brushed over on flesh and grain. The next process consists in paring off loose flesh and inequalities (*dérayage*). This is done on a beam, and with a knife similar to that used in bate-shaving, and shown in A, Fig. 903. This knife has the edge turned by rubbing with a strong steel, and is called *couteau à revers.*

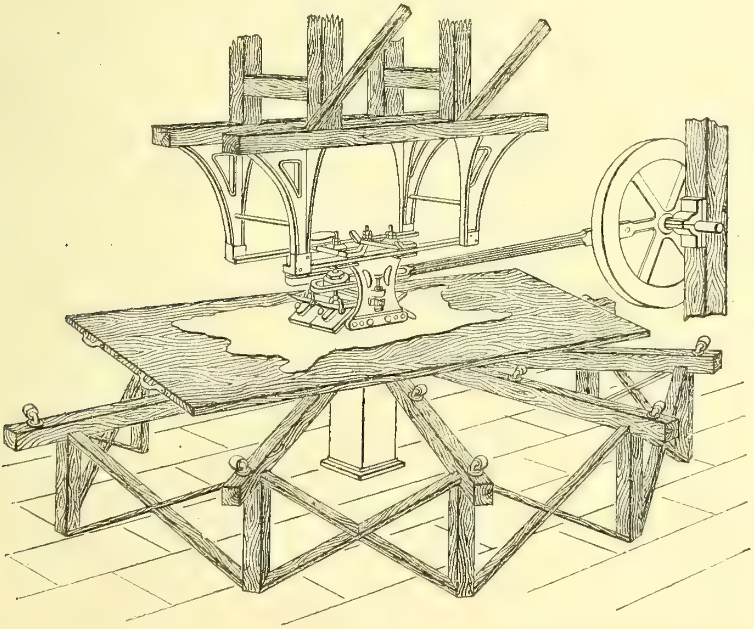
Next follows the *mise au vent.* The skins are first placed in a tub with water or weak tan-liquor for 24 hours; they are then folded and placed in a tub with enough water to cover them, and beaten with wooden pestles for ¼ hour. At the present day, stocks (*foulon vertical*), or a "drum-tumbler" (*tonneau à fouler*), a machine on the principle of the barrel-churn, usually take the place of this hand labour. The skin is next placed on a marble table, flesh upwards, and with one flank hanging somewhat over the edge, and is worked with a "sleeker" or stretching-iron (*étire*), B, Fig. 903. The first two strokes are given down and up the back, to make the skin adhere to the table, and it is then worked out regularly all round the side on the table, so as to stretch and level it. The flesh is then washed over with a grass-brush (*brosse à chien-dent*), the skin is turned, and the other flank is treated in the same way. It is lastly folded in four, and steeped again in water. The next process is the cleansing of the grain. The skin is spread again on the table, as before, but grain upwards, and is worked over with a stone (*cœurse*), set in handles, and ground to a very obtuse edge. This scours out the bloom; after washing the grain with the grass-brush, it is followed by the sleeking-iron, as on the flesh.

The next step is re-setting (*retenage*). For this, except in summer, the skins must be dried again, either by press or in the shed. This is another setting out with the sleeker, and, the skin being dried, it now retains the smoothness and extension which is thus given to it. The skins are now ready for oiling in the grain, for which whale-oil or cod-liver oil is generally employed. Olive-oil, castor-oil, and even linseed-oil may, however, be used, and are sometimes made into an emulsion with neutral soap and water. After oiling the grain, the skins are folded and allowed to lie for 2–3 days before oiling the flesh.

The oiling on the flesh is done with a mixture of *dégras* and tallow, in such proportions as not to run off during the drying. *Dégras* is the surplus oil from the chamois-leather manufacture, which in France is effected by daily stocking the skins with oil, and hanging in the air for oxidation. The *dégras* (*toise*, *moëllon*) is obtained, not by washing the skins in an alkaline ley, as in the English and German method, but by simple pressing or wringing. This oil, altered by oxidation, is so valuable for currying purposes that skins are frequently worked simply for its production, being oiled and squeezed again and again till not a rag is left. It is generally mixed in commerce with more or less of ordinary fish-oil. Eitner recommends, where the *dégras* is of indifferent quality, a mixture of 65 parts *dégras*, 20 of neutral soap (i. e. soap without the usual excess of alkali), and 15 of soft tallow. After oiling the flesh, which is accomplished by extending the skin on the marble table with the sleeker, and applying grease with a sheep-skin pad, it is hung to dry at a temperature of 18°–21° (65°–70° F.). After drying, the surplus oil is removed by a fine sleeker from both flesh and grain, and the skins are ready for "whitening" (*blanchissage*). This consists in taking a thin shaving off the flesh, and was originally accomplished by the shaving-knife on the currier's beam, and some curriers are still in favour of this method. It is now, however, done by a sleeker with a turned edge. The grain then undergoes a final stoning and sleeking, to remove the last traces of adhering oil, and the skin is grained by rubbing it in a peculiar way under a pommel covered with cork. It is then coated on the flesh with a mixture, of which the following is a specimen:—5 parts of lamp-black are rubbed with 4 of linseed-oil, and 35 parts of fish-oil are added; 15 parts of tallow and 3 of wax are melted together and added to the mixture; and, after cooling, 3 parts of treacle. This compound is put on with a brush, and allowed to dry for some days. Finally, the skins are sized over with a glue-size, which is sometimes darkened by the addition of aniline-black.

The preceding account will give some idea of the care and labour expended on these goods in France. In England, cheaper productions are more in vogue, and almost every process is accomplished by machinery. An illustration of the Fitzhenry or Jackson scouring-machine, which is largely employed both for scouring and setting out, is given in Fig. 920.

920.



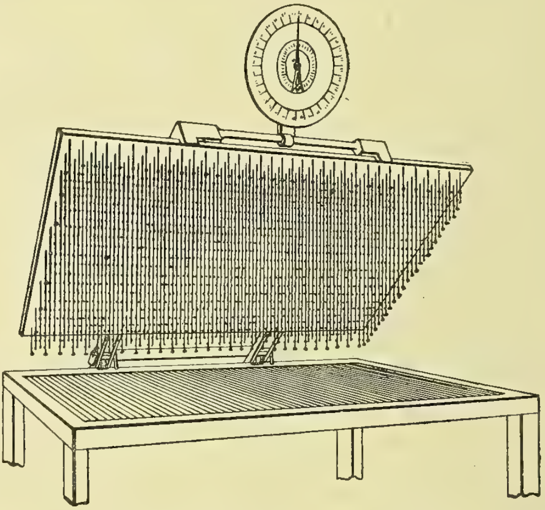
In the case of strap-butts, the currying is, of course, far less elaborate. They are well scoured out, heavily stuffed, and stretched in screw-frames, to prevent their giving afterwards when in use. In England, curried leathers are generally sold by weight, which leads to the use of glucose and other materials to add to the weight. In America, all upper leathers are sold by measure, and this is now ascertained by a very ingenious machine (Fig. 921). The skin is laid on a latticed table, and a frame, from which rows of bullets are suspended, is let down upon it. The total weight

4 K 2

of the frame is indicated by a spring balance, and as the bullets which are over the skin are supported by it, the diminution of weight indicates the measurement.

Enamelled, Patent, or Japanned Leather.—These are terms used to designate those leathers, whether of the ox, the horse, the calf, or the seal, which are finished with a waterproof and bright varnished surface, similar to the lacquered wood-work of the Japanese. The term "enamelled" is generally used when the leathers are finished with a roughened or grained surface, and "patent" or "japanned" are the terms used when the finish is smooth. Though generally black, yet a small quantity of this leather is made in a variety of colours.

921.



Leather destined to be finished in this way requires to be curried without the use of much dubbing, and to be well softened. The English practice is to nail the skins thus prepared, and quite dry, on large smooth boards, fitted to slide in and out of stoves maintained at a temperature of 71°–77° (160°–170° F.), coating them repeatedly with a sort of paint composed (for black) of linseed-oil, lampblack, and Prussian blue, well ground together. Each coating is allowed to dry in the stoves, before the next is applied. The number of coatings varies with the kind of skin under treatment, and the purpose for which it is intended. The surface of every coat must be rubbed smooth with pumice; finally, a finishing coat of oil varnish is applied, and, like the preceding coats, is dried in the stove. The exact degrees of dryness and flexibility, the composition of the paint, and the thickness and number of the coats, are nice points, difficult to describe in writing.

This branch of the leather industry, so far as it relates to calf-skins, is carried on to a larger extent, and has been brought to greater perfection in Germany and France than in England. In the former countries, the heat of the sun is employed to dry some of the coatings. The United States have also brought this style to a high degree of excellence, especially in ox-hides. There, use is made of the oils and spirits obtained from petroleum, and without doubt, French and German emigrant workmen have materially assisted in attaining this high standard.

Leather finished in these styles is used for slippers, parts of shoes, harness, ladies' waist-belts, hand-bags, &c., and has now maintained a place among the varieties of leather for a long period of years.

Morocco Leather.—Morocco leather is produced from goat-skins. Rough-haired or "blue-back" seal-skins are also used, and produce an excellent article; while an inferior description, called "French morocco," is produced from sheep-skins. The skins are unhaired by limeing in the usual way, and are then baited with a mixture of dogs' dung and water. The tanning is done chiefly with sumach, at first in paddle-tumblers, and then in handlers, lasting about a month in all. Sheep-skins are usually tanned through in about 24 hours, by being sewn up into bags, grain side outwards, and nearly filled with strong sumach infusion. A little air is then blown in, to completely distend the skin, and they are floated in a sumach bath, and kept moving by means of a paddle. After the first day's immersion, they are thrown up on a shelf, and allowed to drain; they are then again filled with sumach liquor; when this has a second time exuded through the skin, they are sufficiently tanned, and the sewing being ripped open, they are washed and scraped clean, and hung up to dry, making what are called "crust-roans." The dyeing is sometimes done by brushing on a table, grain side upwards, but more usually the skins are folded closely down the back, flesh side inwards, so as to protect it as much as possible from the influence of the colour, and then passed through the dye-bath, which is now generally of aniline colours. The original oriental method of manufacture for red morocco was to dye with cochineal before tanning, and this is still customary in the East, but is quite obsolete in this country. A grain or polish is given to the leather, either by boarding, or by working under small pendulum rollers, called "jiggers," which are engraved either with grooves or with an imitation of grain. A well-cleaned sumach-tanned skin is capable of being dyed in the finest shades of colour; and this branch of the manufacture of leather has been brought to great perfection.

Russia Leather (Ger., *Juchtenleder*).—This is tanned in Russia with the bark of various species of willow, poplar and larch, either by laying away in pits, or handling in liquors, much like other light leathers, the lime being first removed by bating, either in a drench of rye- and oat-meal and salt, by dog-dung, or by sour liquors. After tanning, the hides are again softened and cleansed by a weak drench of rye- and oat-meal. They are then shaved down, carefully sleeked and scoured out, and dried. The peculiar odour is given by saturating them with birch-bark oil, which is rubbed into the flesh-side with cloths. This oil is produced by dry distillation of the bark and twigs of the birch (see Oils—Birch-bark). The red colour is given by dyeing with Brazil-wood; and the diamond-shaped marking by rolling with grooved rollers.

Much of the leather now sold as "Russia" is produced in Germany, France, and England. It is tanned in the customary way, occasionally with willow-, but more generally with oak-bark, and probably other materials. Economy would suggest the use of such materials as, from their red colour, are objectionable for other purposes, and therefore cheap. The currying is in the usual manner, care being taken that the oil used does not strike through to the grain, which would prevent it taking the dye. The colour is given by grounding with a solution of chloride of tin (100 parts perchloride tin, 30 parts nitric acid, 25 parts hydrochloric acid, allowed to stand some days, and the clear solution poured off, and mixed with 12 volumes of water). The dye-liquor may be composed of 70 parts rasped Brazil-wood, 3 parts tartar, and 420 water, boiled together, strained, and allowed to settle clear. The grounding and dyeing is done on a table with a brush or sponge (see Glove-kid dyeing, p. 1239). The odour is communicated by rubbing the flesh-side with a mixture of fish-oil and birch-bark oil, which sometimes contains no more than 5 per cent. of the latter.

Calf-kid.—Calf-kid is used for light upper-leather, and belongs to a different class from any yet described, being "tawed" instead of tanned. In this respect, and in most details of its manufacture, it resembles glove-kid.

The process is as follows. Selected calf-skins, dried or salted, are the raw material, and after a suitable softening in fresh water, are limed for 2–3 weeks, or till the hair goes easily. They are then unhaired and fleshed in the usual manner, pured with a bate of dogs' dung, scudded, and again cleansed with a bran drench. In Germany, the bran drench is used alone, and is composed of 33 lb. bran to 100 medium skins. Before use, the bran should, especially in summer, be well washed to free it from adhering meal. The temperature of the drench should not exceed 38° (100° F.), and the skins should remain in for 8–10 hours. Lactic acid is produced by fermentation; this removes lime, and is itself neutralized by the products of putrid fermentation which succeeds it.

The tanning is accomplished in a drum with a mixture of alum and salt; and after drying, the skins are again moistened, and worked in the drum with a mixture of oil, flour, and egg-yolk. In the German method, these two operations are combined. Eitner, who has written a series of articles on the process, gives 40 lb. flour, 20 lb. alum, 9 lb. salt, 250 eggs, or about $1\frac{1}{3}$ gal. of egg-yolk, $\frac{7}{8}$ pint ($\frac{1}{2}$ litre) of olive-oil, and 12–16 gal. water, as a suitable mixture. The skins are worked in a drum-tumbler (preferably a square one) for 20 minutes, then allowed to rest ten minutes, and this process is twice repeated. The temperature must not exceed 38° (100° F.), and it is said to be important that the drum should be ventilated by holes at the axis.

The skins are allowed to drain, are then rapidly dried at a temperature of 60°–71° (140°–160° F.), and, after "samming," or damping with cold water, are staked by drawing them to and fro over a blunt knife fixed on the top of a post. They are then wetted down and shaved, either with the moon-knife or ordinary curriers' shaving-knife, and sometimes receive a second dressing of oil, flour, and egg, to soften them still further.

Dyeing black is accomplished either by brushing on a table, or by "ridging" or folding, grain-side outwards, and drawing quickly through baths of the mordant and colour. To prepare them for the colour, stale urine is generally employed. A deeper colour, and one less liable to strike through the skin, is obtained by adding $\frac{1}{4}$ lb. bichromate of potash to 4 gal. of urine, or the following mixture may be substituted with advantage, viz. $\frac{1}{2}$ lb. Marseilles soap dissolved in boiling water, 5 or 6 egg-yolks added, and the whole made up to 4 gal. with water and $\frac{1}{4}$ lb. bichromate of potash. The colour used is infusion of logwood or its extract, or two-thirds logwood, which is best extracted by stale urine or old soak-liquor, with addition of a small quantity of soda (1 lb. to 25 lb. dye-wood). It is fixed and darkened by a wash of iron-liquor (1 of protosulphate of iron in 75 of cold water). After being again dried, the skins are grounded with the moon-knife, and rubbed over on the grain with a composition containing oil, wax, &c., and are finally ironed with a flat-iron, to give them a fine and smooth surface. Eitner gives a recipe for the gloss:—1 lb. gum arabic, $\frac{1}{2}$ lb. yellow wax, $\frac{1}{2}$ lb. beef-tallow, $\frac{3}{4}$ lb. Marseilles soap, 2 lb. strong logwood infusion, and 1 gal. water. The water is brought to a boil in an earthen pot, and then the soap, wax, gum, and tallow are added successively, each being stirred till dissolved before adding the next, and lastly the logwood. After boiling for an hour, it is allowed to completely cool, being incessantly stirred during the whole process.

Glove-kid.—This branch of leather manufacture is mainly carried on in Germany, Austria, and France. In Germany and Austria, lamb-skins are principally employed; in France, kid-skins. For fine gloves, the skins of very young animals only can be used. The commonest style of manufacture is as follows:—The soaking of the dried skins is effected in large wooden tubs (*Kufen, Bottichen*), and occupies on the average 3–4 days, according to the character of the soak-water, the size of the skins, and the time they have been stored. The skins, when thoroughly and uniformly softened, are unhaired, either by painting the flesh-side with a thin paste of lime, or in lime-pits. In unhairing by painting (*Schwöden*), the skins, after coating the flesh-side with lime, are folded together, so that the lime comes as little as possible into contact with the wool, and these bundles or "cushions" are placed in a tub, in which they are most frequently covered with water. After unhairing on the beam with a blunt knife, the skins must be limed for some days, in order that the leather may stretch well, a quality which the Germans denominate *Zug*. By this method of unhairing, the wool is preserved uninjured, but it is not suitable for the finer sorts of leather. The unhairing in lime-pits is done either with gas-lime (*Grünkalk*), or, as is now almost exclusively the practice, with the so called "poison-lime" (*Giftäscher*). This is prepared by mixing red arsenic (arsenic sulphide) with lime, while it is being slaked, and is at its hottest. The calcic sulphydrate (and perhaps sulpharsenite) thus formed hastens the unhairing, and gives the grain a higher gloss. Well-conducted establishments now avoid as much as possible the use of old limes, which produce a loose, porous leather, with a rough, dull grain. The limeing lasts on the average ten days, and is of the greatest importance. It is essential that the interfibrillary substance shall be dissolved, that the leather may have the quality known as *Stand*, that is to say, may be strongly stretched in either length or breadth without springing back. It also depends upon the limeing (and this is of special importance in the case of lamb-skins), whether the tissue of the fat-glands is well loosened, so that the fat, either as such, or as lime- or ammonia-soap, may be readily and completely worked out. Skins in which this is neglected can never be properly dyed.

When the hair (or wool) is well loosened, the skins are rinsed in water, and then unhaired on the beam with a blunt knife. The water employed in washing should not be much colder than the limes, or it will prevent the hair from coming away readily. The wool or hair is washed and dried for sale. The skins are thrown into water, to which a little lime-liquor has been added, to prevent precipitation of the lime in the skins by the free carbonic acid of the water, which would have the effect of making them rough-grained.

Next comes the first fleshing (*Vergleichen*) or "levelling." By this, the loose cellular tissue on the flesh-side is removed, together with the head, ears, and shanks, and the flanks are trimmed. The skins are then again thrown into water, softened with lime-liquor as above described, and then into a bate of dogs' dung. This is prepared by stirring up white and putrid dogs' dung with boiling water, and straining it through a sieve or wicker basket. The bate must be used tepid, and not too strong. The skins "fall" (lose their plumpness) in it rapidly, and become extremely soft and fine to the touch; and the fat-glands, remaining hairs, and other dirt, can now be very readily scudded out. So far no completely satisfactory substitute has been found for this somewhat disgusting mixture, but it has been noted that guano will produce similar effects. With regard to the mode of action of the dung bate, much has been speculated without proof, and exact analytical evidence is wanting; but, no doubt, a weak putrefactive action goes on, as may be deduced from the presence of *bacteria;* further, the ammonia and weak organic acids present in the putrefying dung are capable of acting on fat and lime; and finally, a direct mechanical effect seems to be produced, difficult to describe, but favourable to the succeeding manipulation. Too strong bates, or too long continuance in them, produces evident putrefactive effects on the skins.

When the skins come out of the bate, they are stretched and worked (*abgezogen*) on the flesh with a sharp knife, and any remaining subcutaneous tissue is removed. This constitutes the second fleshing. They are then rinsed in warm water, and beaten with clubs (*Stoss-keule*) in a tub, or worked in a tumbler-drum (*Walkfass*), in either case with a very little water only; and finally brought into a tank of water, not too cold, and kept in constant motion with a paddle-wheel.

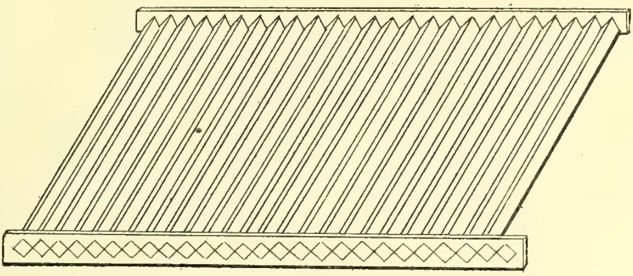
The skins are next cleansed on the grain-side by working on the beam with plates of vulcanite with wooden handles, so as to remove fat, lime- and ammonia-soaps, and other lime compounds, together with all remaining hair or wool. The skins are now a second time washed in the "paddle-tumbler," first in cold, and then in tepid water; and after allowing the water to drain from them, they are transferred to the bran-drench.

Bran-drench.—This is prepared by soaking wheaten-bran in cold water, diluting with warm water, and straining the extract through a fine hair-sieve. Sufficient of the liquid must be employed to well cover the skins, and the temperature may range from 10° (50° F.) to 20° (68° F.). These conditions are favourable to bacterial activity, which comes into play, and, on the one hand, evolves formic, acetic, lactic, and butyric acids, which dissolve any remaining traces of lime, and on the other, loosens and differentiates the hide tissue, so as to fit it to absorb the tawing solution (*Gare*). Much care is required in the management of the bran-drench, especially in summer, since the fermentation readily passes into actual putrefaction. The tawing-mixture is composed (like that employed in the fabrication of calf-kid, q. v.) of alum, salt, flour, and egg-yolks, in a quite thin paste. The skins are either trodden in it with the feet, or put into a tumbler-drum with it. Kathreiner pointed out, some years since (in vol. i. of 'Der Gerber'), that a mixture of olive-oil and glycerine might be partially substituted for the egg-yolks, in both the tanning and dyeing of glove-kid leather.

The tawed skins are now dried by hanging on poles, grain inwards. Rapid drying in well-ventilated, but only moderately-heated, rooms is essential to the manufacture of a satisfactory product.

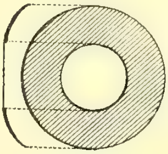
The dry leather is rapidly passed through tepid water, and after being hung for a very short time, to allow the water to drain off, is trodden tightly into chests, and allowed to remain in them for about 12 hours, so that the moisture may be uniformly distributed. It is then trodden on hurdles (*Horden*), composed of square bars of wood, joined corner to corner, so as to make a floor of sharply angular ridges, Fig. 922. The next operation is stretching over a circular knife, called the *Stollmond* (*stollen*, Eng. "staking"), shown in Fig. 923; then the leather is dried nearly completely, and staked again.

922.



Dyeing.—The dyeing of glove-kids is done in two ways:—*a.* The skins are plunged into the dye-bath (*Tunkfarben*). In this way, all light colours are ordinarily produced, such as *gris-perl* (pearl-grey), *paillé* (straw-yellow), *chamois* (reddish-yellow), silver-grey, aquamarine, &c. *b.* The skins are spread on an inclined or rounded table of stone or metal, and brushed over, on the grain side, first with a mordant (*Beitze*), then with the dye-liquor, and lastly with a solution of a mineral salt. The mordant serves to fix the colour on the surface of the skin, to prevent its striking through, to produce certain modifications of colour, and to enable any parts of the skin which yet contain fat to take the colour evenly with the rest. To satisfy these conditions, the composition of the mordants is very varied. Bichromate of potash, ammonia, potash, soda, and stale urine are among the most frequently employed, seldom separately, but usually in a mixture containing two or more.

923.



Dyestuffs of vegetable origin have always held the first place. These most in use are logwood (*Blauholz*), Brazil-wood (*Rothholz*), the two fustics—*Cuba Gelbholz* (*Morus tinctoria*) and *Ungarisches Gelbholz* (*Rhus cotinus*), several species of willow-bark and of berries, indigo-carmine, and indigo dissolved in sulphuric acid.

Aniline colours used alone remained in fashion for a short time only, but are now usefully employed as top-colours (*Ueberfarben*), viz. brushed in very dilute solution over vegetable colours. In this way, particularly tasteful shades of green, violet, and marine-blue may be produced.

After the mordant has been applied once or twice, and the colour 3–6 times, a wash (*Ueberstrich*) containing some metallic salt is generally applied, with the object either of bringing out the special tone required, or of making the colour more lively and permanent. The so-called "vitriols" are mostly employed: "white vitriol" (zinc sulphate), "blue vitriol" (copper sulphate), "green vitriol" (iron sulphate), and occasionally other salts.

Before dyeing, the greater part of the flour, salt, and alum must be removed from the skins by washing with tepid water; and therefore require a second feeding (*Nahrung*) of egg-yolk and salt. In the case of the skins which are dyed by plunging into the dye-vat (*Tunkfarben*), this is done after the dyeing is completed. In that of brush-dyeing, before the dyeing process.

After the dyeing, the skins, if dipped, are wrung out; if brush-dyed, sleeked out with a brass plate, to get rid of superfluous water. They are then dried in an airy room. Before staking (stretching), the skins are laid or hung in a damp cellar, or in moist saw-dust. They are staked twice: once damp, and once nearly dry.

Skins which are much damaged on the grain, or otherwise faulty, are smoothed with lump pumice on the flesh side, either by hand or machine. They are then dyed on this side, mostly by dipping, but occasionally with the brush, in which case, the method described is slightly modified.

Indebtedness is acknowledged to F. Kathreiner, of Worms, and David Richardson, of Newcastle, for much information on the production of light leathers.

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(See Skins; Tannin.) H. R. P.

LINEN MANUFACTURES (Fr., *Industrie toilière, linière*; Ger., *Leinenmanufactur*).

The spinning and weaving of flax is undoubtedly the second, if not the oldest, of the textile arts. Evidence of the truth of this statement abounds on every hand. The paintings in the tombs of Upper Egypt, in which the processes of manufacture, from the pulling of the flax to the weaving and finishing of the cloth, are vividly represented, taken in conjunction with the remarkable preservation of the cloths in which the ancient Egyptians enshrouded their embalmed dead, render its certainty beyond dispute. Every fact in connection with this subject, which has been brought to light, tends to show the very high degree of perfection to which these people had carried the industry. Whether they invented the art of weaving, or received it from a people older than themselves, it is useless now to inquire. Certain it is that, after Egypt had long been the emporium of manufactures and commerce, the art under notice gradually spread beyond its boundaries into neighbouring lands. The Israelites, on their departure from captivity, carried with them a knowledge of the industry which they had acquired during their sojourn by the Nile. Phœnicia possessed the art at a very early period, and Sidon, Tyre, and Carthage were successively great centres of commerce in "purple and fine linen." The cultivation and manufacture of flax became a considerable industry in ancient Greece and Rome. In these states, it first appears to have attained such dimensions as to become a separate handicraft or trade, though far from having become extinct as a domestic institution. In the former country, so high a degree of excellence was attained, that when the simplicity of the means the artisans possessed is borne in mind, the results achieved command the admiration of experts of the present day; and Spain, Gaul, and Germany doubtless received the art from these sources. During the period following the fall of Rome, the linen manufacture, along with other arts and industries, was nearly destroyed. The maritime and free cities of Italy were the first to accord renewed encouragement to the flax industry, and Bruges, Hamburg, and other towns became eminent centres. The Flemings at a very early period became flax manufacturers, and great numbers earned their subsistence by weaving, and disposing of their productions in France; under Baldwin III., and several subsequent rulers, the woollen and linen manufacturers of Flanders rose to great importance, and maintained their high rank until intestine quarrels and religious persecutions drove the craftsmen to foreign lands. From the 6th century down to the present day, Germany has possessed a manufacture and trade in linen goods of considerable extent and importance, while the raw material has been largely cultivated in its alluvial districts. The Netherlands for a long time manufactured, and otherwise traded with great benefit, in linen fabrics. Since its separation, Belgium has devoted great attention to the cultivation and manufacture of flax, and as regards the production of the raw material, now stands at the head of the industry. France for more than 1000 years has grown and manufactured flax, the fibre raised by the farmers being dressed, spun, and woven for domestic use long before the modern system of manufacture was originated; during the current century, the industry has made considerable progress, and though formerly spread over a large area of country, it is now mainly concentrated in particular localities, situated in the northern and western provinces: Flanders (French), Picardy, Isle of France, Normandy, Maine, and Brittany. Russia raises large quantities of flax, which is exported in the unmanufactured state; for centuries past, it has possessed a domestic manufacture, spread over its extensive dominions, and since machinery has been applied to it, the country has made fair though not great progress in adapting itself to the changed circumstances; formerly its linen manufactures, being composed of the better qualities of flax, stood high in various markets, but they have been supplanted to a great extent by the cheaper fabrics produced from jute and jute mixtures in Dundee. The states of N.-W. Europe—Denmark, Norway, and Sweden—possessed an industry in this article of ancient origin, but of only the smallest importance. Switzerland is prevented by geographical location, and unsuitable soil, from excelling in the production or manufacture of flax; but notwithstanding these disadvantages, it has succeeded in founding a considerable industry, the raw materials being imported from the surrounding countries, and the manufactured fabrics supplying the home market, and finding their way into Italy, Austria, and the Danubian States. The linen manufactures of other foreign countries are of the most insignificant character.

Flax and its manufacture have long been known in Great Britain and Ireland. The art of manufacturing the fibre seems to have been introduced by the Belgæ, and the existence of a manufactory of woollen and linen cloth at Venta Belgarum (Winchester) is recorded in the 'Notitia Imperii.' During the troubled period following the withdrawal of the Romans, the art rapidly fell into decay, and it was not until the Saxons had established their dominion that attention was again directed to the manufacture of wool and flax. Before the close of the 7th century, weaving had made great progress, and the Anglo-Saxon females had gained wide repute for their skill. Records show that the materials chiefly or solely used were wool and flax, fabrics manufactured from the latter fibre being worn as under-garments by all persons of moderate rank or wealth. In the interval between the 7th century and the Norman invasion, further progress was made; the Bayeaux Tapestry commemorating that event has for its foundation a linen fabric, 20 in. wide and 214 ft. long, the figures being worked in with dyed woollen yarns. Among the invaders, were many Flemish weavers, who were subsequently followed by others of their countrymen; and guilds or fraternities of these artsians were soon founded. In 1253, fine linen was first made in Wilts and Sussex; and in 1272, Irish linen was in use at Winchester. In Wales, the manufacture was established at an early date, records stating that, in the commencement of the 14th century, linen was a common article of wear. Fine linen was at this time imported from Rheims. The linen industry fluctuated greatly during the next three centuries, sometimes being stimulated into considerable activity and growth, and again left to neglect and decay. At the commencement of the 18th century, it had obtained a position of great importance, and those engaged therein, in conjunction with the woollen manufacturers, were sufficiently powerful to obtain the passing of many protective or prohibitive laws directed against foreign goods, especially the calicoes and muslins of India. The introduction of the cotton manufacture soon after this time had a depressing influence upon the linen trade. At first, cotton yarns were only used for weft; but after Arkwright's invention had been perfected, they were made strong enough to serve for warp purposes, and the growth of the cotton trade subsequently almost destroyed the linen manufacture, both spinners and weavers turning their attention to the new fibre, and engaging in the production of the new and popular fabrics. Since that time, in England it has been a decaying industry, and at present there is little of it surviving.

In Ireland, the course of the linen manufacture has been in a great measure parallel with that of this country. For a long period, the country was noted for the production of the raw material, much of which was exported to England in the fibre, and also in yarn; here it was woven into cloth, and to some extent returned again for sale. Towards the middle of the 17th century, linen manufacturing was thoroughly established in the island; Ireland had also at that time a considerable woollen trade, but this was discouraged for political reasons, and the linen trade was stimulated by every available means. From the beginning of the 18th century, its course has been one of steady progress, and, owing to the comparatively early adoption of machinery in the different processes, the present century has witnessed a great expansion.

In Scotland, linen manufacturing was established at a very early date, and was often encouraged by the Government. It also suffered the usual fluctuations incident to favouritism. The industry was spread over almost the whole of the country, and attained, owing to the introduction of Flemish and other skilful weavers, a high degree of excellence. More recently, when machinery became generally adopted, it concentrated in the localities which have since acquired repute for their excellent productions. Of late years, however, the linen trade has to some extent been overshadowed by the progress of the jute manufacture.

In all the countries ancient and modern over which the cultivation and manufacture of flax extended, the implements in use, until towards the close of the last century, were of the simplest kind. The excellence of ancient textiles was the result purely of skilful manipulation. It was not until the Greek and Roman periods that any real advance was made in the art of manufacturing linen. The method of spinning then adopted was to make a loose ball of the fibre, into which the distaff was inserted, the lower end being held under the arm in such a position as to allow of the fibre being conveniently drawn off by the fore-finger and thumb of the right hand. The spindle, on its lower extremity, had a whorl of wood or other material, by which it was kept steady, and its rotation was assisted. The upright loom seems to have been preferred. The *stamen* or warp was passed over a cross-beam or rail on the top of the loom, and kept in a state of tension by being divided into sections, with stones suspended from each. A set of lease-rods were used to separate it into equal portions, the threads alternating on each side, as in the modern method. The heddles were formed of threads, fastened at one end to a straight rod, and having at the other end a ring or loop, each containing a thread of the warp. The number of these varied according to the texture of the cloth. The weft was carried on a spindle or bobbin. In weaving, the shed was formed by drawing one or more leaves of the heddles forward at one time, and passing the pirn through the open shed. The tension upon the warp drew these back into their first position, when the next in order were drawn forward in a similar manner, the weft was again inserted, and the operation was repeated. Each thread of weft was passed to its position by the *pecten* or comb, which fulfilled the office of the modern reed. The teeth of the comb were inserted between the threads of the warp, and thus made to drive the pick of weft close to the preceding one, in order to obtain a firm cloth.

No important improvement took place in the means or processes employed until the invention of the hand spinning-wheel. The first step beyond the distaff and spindle, which had sufficed for the necessities of mankind through many centuries, was the invention of a rude frame for holding both these instruments, thus relieving the operator's hands for other duties. This arrangement, about the commencement of the 16th century, was much improved by having the spindle mounted for driving by a belt from a large wheel turned by hand. A treadle was soon after added for working it by foot. The form of the loom, too, had undergone a great change, having assumed one which allowed the warp to be arranged horizontally in the frame. The healds were modified so as to admit of being worked by foot-levers or treadles, and the batten or slay containing the reed was suspended inside the frame from the top, and made to oscillate upon centres. This enabled the weaver to drive home every pick of weft with greater facility, speed, and ease than by any previous arrangement, and tended greatly to increase the production. The shuttle was passed through the shed from hand to hand, as before, and when wide cloths were being made, two weavers were required to operate one loom. As linen and woollen were the only two fibres wrought to any important extent, both branches of the industry appropriated these improvements in nearly every country, as soon as the limited intercourse between them would allow.

The Saxon wheel, soon after introduced, was more perfect than the preceding. The spindle of this wheel was supplied with a bobbin, on which the thread was wound, and with a "flier" revolving at a greater speed than the bobbin, whereby the fibres were twisted as required. This constituted a great advance; and so perfect was its action that it has never been surpassed to this day. Its principle is still embodied in many of our preparing- and spinning-machines.

This wheel was a long time before it supplanted the more antique instruments, but during the 18th century, the latter finally disappeared. About 1764, it was further improved by the addition of another spindle. This was called the "two-handled wheel," and maintained its ground until the beginning of the present century. This, in its day, was a very efficient instrument. Its frame was mounted on three legs. To the right of the operator, was a spoked wheel, about 2 ft. in diam., on the axle of which was a crank carrying a connecting-rod, whose opposite extremity was attached to a treadle operated by foot. On the left, the two spindles were mounted in a part of the frame, which rose to a suitable altitude. The spindles were furnished with small whorls, grooved on their periphery, for the reception of the driving-bands. The large wheel was also hollowed around the rim for the same purpose. The driving-bands were composed of hard-twisted woollen or flax yarn, the selection depending upon the fibre for which the machine was being used; sometimes gut was the material. Each spindle had a flier for twisting the thread, which was wound upon a "bobbin," a thin wooden tube, fitting rather loosely upon the spindle. The flier revolved with great rapidity, the bobbin following more slowly, being held in check by the thread, and revolving only at a rate sufficient to take up the yarn as it was delivered by the spinner. The distaff was attached to the wheel in the most convenient position for permitting the fibres to be drawn off with facility by the hands of the worker, both being employed in drawing the material and forming the threads. These, in process of spinning, were from time to time shifted upon a series of bent wires, so as to fill the bobbins as evenly as the appliances would permit. The threads were moistened with saliva by the worker, to make the fibres more pliable and yielding to the torsion applied, and thus more readily form a solid thread. The filled bobbins were placed upon a pin held in the left hand, and their contents were wound upon a flax-reel, 120 rev. of which constitute a "cut." This quantity was tied together, and others were added until there was a sufficient number to form a hank, when it was removed. In spinning on both the one-thread and two-thread wheels, great expertness was attained by the best workers, and their yarn was remarkable for solidity, smoothness, roundness, and evenness.

The hand-wheel did not give way to its mechanical competitor until the close of last century; and before disappearing, had applied to it the mechanical traverse of the flier, for laying the threads in even layers upon the bobbin by automatic means, instead of passing them successively along the series of crooked guide-wires by hand.

The successes of Hargreaves, Arkwright, and Cartwright in the invention and application of machinery to the kindred industry of cotton-spinning, during the latter half of last century, soon suggested a similar course in relation to the flax manufacture. This was quickly followed, and very soon correspondingly favourable results were achieved, the new machinery superseding for ever the appliances which had sufficed for so long. The lead in this movement was taken by an optician and a clock-maker, named Kendrew and Porthouse, of Darlington. The former appears to have been the prime mover. An inspection of the Lancashire cotton machinery resulted in a patent being taken out in 1787, described as being for "a mill or machine upon new principles for spinning yarn from hemp, tow, flax, or wool." Several of these machines were fitted up and successfully worked for some years in a small mill situated on the Skerne, at Darlington. They soon attracted the attention of Scotch manufacturers, who erected some on the same principle, and paid a royalty to the inventors. But the progress made was not very great or satisfactory. The machinery was rude, and roughly finished, and the work was correspondingly difficult and inferior. It was many years before machine-spun yarns equalled the quality of those obtained from the hand-wheel. Experience dictated successive improvements and inventions, which so far perfected the yarns that in the early part of the present century they began to supersede hand-spun yarns, which finally disappeared. Many inventors contributed to this result, and their improvements will, to some extent, come under notice presently. The linen manufacture as now conducted requires large establishments, furnished with expensive machinery, and backed by considerable capital, to work with advantage. There is also needed a great amount of technical knowledge, which is called into requisition at every stage of the process, from the selection of the raw material to the time when it emerges from the manufacture in a finished state ready for the consumer. Without these essentials, there is considerable risk of failure.

Flax (see Fibrous Substances—*Linum usitatissimum*), after undergoing the treatment necessary to prepare it for the market (pp. 964–978), and passing into the hands of the manufacturer, is sent into the store of the spinning-mill, arranged in separate piles or lots, according to quality or growth, and ticketed with the number allotted to the grower from whom it has been purchased. The particulars of these lots are carefully taken down, and entered in the store-book for future reference. This is necessary in order to enable the selection for working to be made to the best advantage, because successive purchases made from one grower are found to be the most uniform in length, strength, and colour, having been grown upon the same soil, and from the same quality of seed, and retted in the same water. Similarity in these respects enables the first process, "roughing," to be performed more satisfactorily than if the fibre varied in its chief qualities. The first process being performed well does much towards assuring satisfactory results in the end.

Roughing.—"Roughing" is conducted as follows:—Scutchers make up the flax for market in bundles of 14 lb., constituting a "stone" of flax. Each stone contains 5–8 "stricks" or handfuls of finished flax, and each strick is composed of two "fingers," two of the small lots that have been treated at one operation in the scutching-process. The "rougher," having been supplied with his parcel of flax, about 2 cwt., takes one of the stones, and separates it into stricks and again into fingers. Holding one of the latter in his left hand, with the butt or root-end from him, he with his right hand separates as much flax from the bulk as he can conveniently hold between his fore-finger and thumb, being careful to select those fibres that have their ends level with each other. With a quick jerk of his right hand, he draws the selected fibres from the bulk, and swinging his arm around, brings them down upon the table in a semicircular form, with the convex side towards him. This operation is repeated, the rougher taking care to have all the pieces as nearly as possible of the same size, which is essential to the proper performance of the roughing, and being careful also to lay the pieces so as to form a straight row on his table. This is called "piecing out," and is continued until the rougher has made a pile of pieced-out flax sufficient to occupy him for an hour or more in "rough dressing." This he commences by grasping a "piece" near the "top-end"; leaving nearly the whole length before his hand, he jerks it behind him, and by drawing it suddenly back, thoroughly loosens it, and brings it down well spread upon the pins of the hackle, which is firmly bolted to the bench on which he is at work. Having gripped the piece near the top, as he proceeds to pull it through the hackle, all the short fibre is retained in the pins by the root-end, which is the object sought. He next takes the root-end of the piece between the finger and thumb of the left hand, and placing it over the corner pins of the hackle, draws it through with his right hand, leaving the weaker fibres with those previously in the hackle. Then, moving his hand down the piece a little towards the middle, he places it upon the portion in the hackle, in such a position that, when the latter is drawn through the pins, the ends of all the portions shall fall exactly level. Should the extremities be slightly irregular, he levels them by drawing out the projecting ends, and placing them in order. The operation is completed by the rougher next taking the top-end of the flax, and, by a quick turn, wrapping it around his right hand, and keeping the end that he is roughing well spread out between his finger and thumb, he throws the piece a second time over the hackle, draws it steadily through, and clears the remainder of the short fibres out of it. Again taking the root-end in his left hand, he laps it round the "touch-pin," a sharp, square, or triangular steel pin, fixed upright in a block of hard wood, fastened to his bench on the left of his hackle, and breaks off all the loose, short, and straggling fibres that remain, thereby securing a perfectly square root-end. The top-end is then, with one or two exceptions, treated in a similar manner, after which the piece is placed upon the heap of roughed flax, the rougher taking care, in withdrawing his hand, to leave in each a partial twist, so as to keep them distinct, for facilitating the succeeding operation.

Roughing is very expeditiously performed. In roughed flax, there are about 5–9 "pieces" in the lb., and in a day's work of 10½ hours, a good rougher will complete about 300 lb., or 10–14 cwt. a week. The flax as thus prepared is termed "longs"; the portions broken off around the touch-pin, after being cleared from the tow, are weighed in with the longs, and called "shorts," being subsequently kept distinct. Roughers earn 15–20*s.* a week, according to their capability, being paid at the rate of about 1*s.* 9*d.* a cwt. High-class qualities of flax, having been carefully prepared for the market, generally need less dressing than other descriptions, and low qualities do not repay much expenditure upon them. The former include Belgian, Dutch, English, and French, whilst the latter are mostly composed of Russian, German, Italian, and some Irish sorts. The rate of pay for dressing these different sorts varies proportionately to the labour spent upon them. Irish flax requires most dressing, being as a rule carelessly prepared for the market.

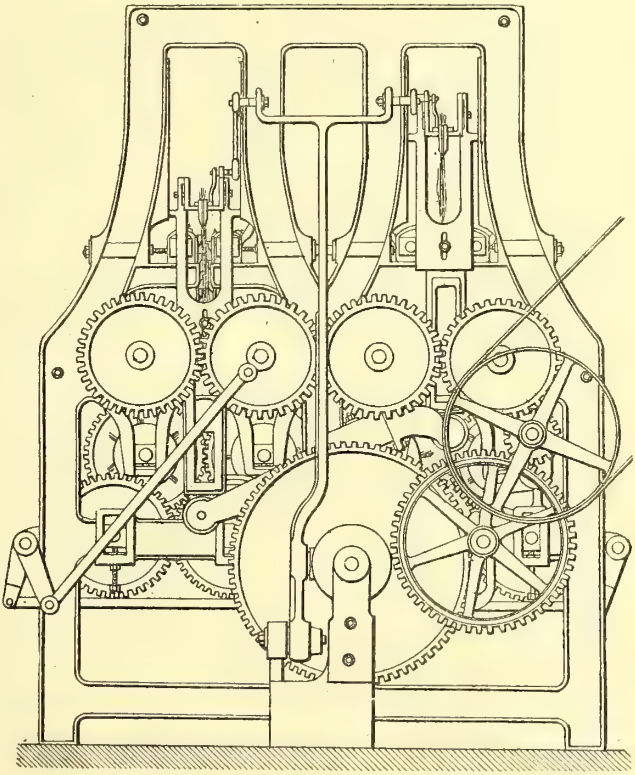
Machine-hackling.—After undergoing rough dressing, the material is brought forward to the next process, machine-hackling. Each fibre of flax, being composed of a number of finer filaments bound together by a natural gum, is capable of being chemically separated to its ultimate fibres. It is not often that this is done, however, and perhaps never for manufacturing purposes. The amount of splitting which the fibre undergoes in machine-hackling depends upon its quality, and the purpose for which it is destined. There are several varieties of machines constructed for accomplishing this object, all possessing particular merits, and being generally efficient.

The hackling-machines in a flax-mill should not be all alike in fineness, nor adapted for exactly similar work. Should the mill not possess more than three, one each should be fitted for coarse, medium, and fine work, because it is certain that, with the best care in purchasing the raw material, these three grades will come to the front in the necessary classification. The "parcels" from the "roughing-shop" having been allotted to appropriate machines, the attendant who serves the operatives in charge of the hackling-machine, generally a boy, gives them the shorts of each parcel to put through first, to serve as a distinguishing mark between that and the preceding parcel, which enables an accurate account to be taken of the weight of the longs obtained from each 2 cwt. The flax of each parcel, as the machining goes on, is made up into bundles of about 10 lb. each, termed "tipples," by a boy who attends a number of machines, and who is technically called a "tippler." His task is to go round and make up these tipples, and to answer the call of the hackler when his parcel is finished. The tipples, having all been put into a basket, are taken to the weighing-machine or scales, where the nett weight is ascertained; another boy at the same time brings the tow, the particulars of which are also taken, and entered upon a ticket. The weights being added together, the total should come to within a lb., or thereabout. of the weight of the parcel.

The feeding of the machine is performed as follows:—The filler—a boy—takes two pieces of flax from that received from the rougher, which he spreads upon a metallic plate, about 12 in. by 4, and which has a bolt called the "holder" fixed in the centre. A piece is spread on each side of this bolt, all except about 12 in. falling over the holder. A top plate is next placed upon the bolt, which is also a screw, and by means of a nut, the plate is firmly screwed down, and made as fast as if held in a vice. The faces of both plates are covered with corrugated indiarubber or cloth, in order to increase the security of the hold. The attendant boy, called a "filler," lifts the secured flax into the head or holder-channel of the machine, which is a "lifter," or rising and falling bar, having a vertical traverse of 12–18 in., or other required distance, according to the length of the flax. Inside the channel, is a rack, working upon a slide, which, by means of deflectors, takes the holders upon being placed in the machine, and, at each ascent of the head to the top of its vertical traverse, shifts the holder laterally a distance equal to its own length, so that, on its next descent, the flax in the holder which has been moved passes between the vertical sheets as before, but in front of a finer set of hackles. These sets of hackles are called "tools," and the quantity varies according to the size of the machine, and the requirement of the work. The Horner machine may have 6–12 tools; in this case, the breadth of the tool will vary from about 8½ to 11½ in., there being little difference in the frame of the machine, which is generally 11–12 ft. in length. According to the number of tools contained in the machine will be the lifts of the head to complete the lateral traverse of each holder, when it will be thrown out, with one half of the fibre it contains—the portion hanging down—completely hackled. The vertical traverse of the head is obtained by the action of a horizontal lever, working on a centre stud, set below and at right angles to the heads. At a short distance from the above stud, is a strong iron pin fixed in the side of the lever, having a runner encircling it, which is confined in a groove cast in the side of a large wheel, called the "wiper," and this, by its revolution, raises or lowers the runner in a manner corresponding to the direction of the groove. The fixed pin upon the lever being contained in the runner, the rocking motion is thus communicated to the lever, and by its means, the head-slides resting upon its extremities are alternately raised and lowered. On the outside of the wiper, is another groove, of a different shape from the former, by means of which the lateral traverse of the holders is effected. This groove has a runner also, which is connected with a vertical lever, that midway in its length has a V-bend, which is held in a given position by a stud-pin carried by a bracket upon the frame between the sheets. The opposite extremity of this lever is bifurcated, the arms being connected with rods working detents in the head-channel, which are adjusted so as to draw the holders when the head is at the top of its vertical traverse; the same movement carries the detents of the other head, which is at its lowest point, backwards to be ready for bringing forward another holder. The arrangement of the head is such that there is a holder for each detent, and one of the latter for every tool. The consequence is that, at every elevation of the head, and shift of the holders, one of the latter is thrown out at the end of its lateral traverse. This is lifted down by a boy, who is technically called a "changer," and laid flat upon a bed on the table, in such a manner as to cause the hackled portion of the flax to fall evenly over another holder, similarly placed to receive it, or rather sufficient of it to secure a firm grip as before; and to subject the unhackled part, when placed in the second head of the machine, to the certainty of being hackled or cut precisely as the first has been.

The sheets of a hackling-machine consist of endless leather straps, of about $5\frac{1}{2}$ ft. circumference, passing over two rollers, the bottom one of which is the driver, and the top one merely a carrier. The former is 9 in. in diameter, and is furnished with iron bosses on its ends and centre, which have catches on their surface, bearing upon the straps and bars, and thereby causing the sheet to revolve. The bars just mentioned are of iron, the full length of the machine, and 1 in. broad by $\frac{1}{4}$ in. thick; they are secured to the straps at their extremities and centres by screws. The hackle-stocks are screwed to these bars, and thus form a revolving sheet of steel pins. On the inside of the end bosses, and on both sides of the centre, grooves or notches, for the reception of the stripper-rods, are cast. These rods are plain strips of tough, pliable wood, $1\frac{1}{2}$ in. by $\frac{3}{8}$ in. thick, and sufficiently long to reach from boss to boss. On the extremities, cast-iron ends are riveted. The rods, being pliable, are bent a little in order to get their ends into the grooves of the bosses; when inserted, they spring back again, and have a certain amount of play. As the roller revolves, they fall forward so as to come into contact with the points of the pins, which are thus stripped of the tow they have combed from the flax through which they have passed. This tow falls upon a "tow-catcher" in close proximity, which, when it has received each contribution, deposits it in a box below the machine. The top or carrier-rollers bearing the sheets are adjustable, by which means the pins in working can be set so as to "face up" to those of the corresponding sheet, or to intersect them, as may be deemed most desirable. This system of stripping by means of rods has been received with considerable favour, but experience has shown that in using some sorts of flax it is not perfect. There exudes upon the pins from these sorts a resinous oil, that causes the pins to get clogged with tow, from the failure of the rods to clear it away.

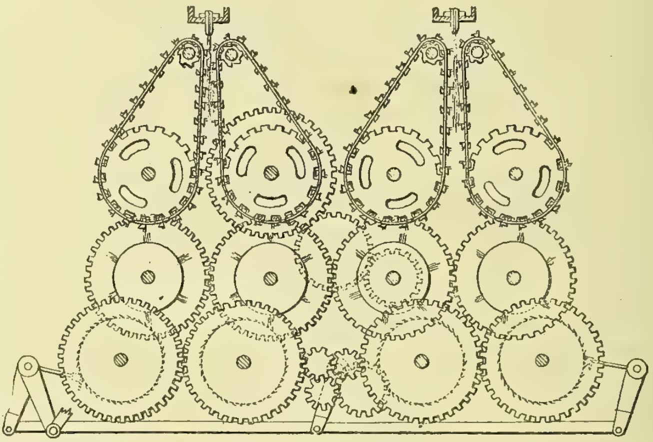
924.



The consequence is that many prefer the older system of the revolving brush and doffer, shown in side elevation and section in Figs. 924 and 925; but with these also there are difficulties, as they only cleanse one side of the pins. The accumulation of oil upon the latter has, however, been thoroughly obviated by an invention applicable to the stripper-rod system, by R. W. McDowell, Belfast, and which has been secured by Horner. This consists in the introduction of a revolving brush, capable of having the direction of its revolution reversed, by which means, it clears itself and cleans the back of the pins at the same time.

Flax which is hackled in the full length of its fibre is called "long line," and the machine is arranged in its details accordingly, being termed a "long-" or "cut-line" machine. For the finest yarns, however, it is necessary to cut off both ends of the fibre, in order to obtain the regular and even portion of the middle of the fibre, the ends varying greatly from each other and from the middle. The "middle" thus obtained is usually 12–18 in. long; from very long flax, it is sometimes desirable, in order to avoid waste, to take out two middles, which will each be 9–12 in. in length. These are called "short middles." At other times, only one end of the flax is cut off; when this is the case, they are called "long middles." The ends are sent to the carding-engine, and carded into tow. Less labour in roughing is bestowed upon flax which is intended for cutting, as it is simply drawn over the hackle to straighten the fibres, the "pieces" also being made much larger. This is known as "stacking." The flax is then carried to the breaking-machine, usually called the "cutter," which contains one or two sets of fluted iron rollers, and a circular knife revolving at 600–1000 rev. a minute. The fluted rollers carry the flax in and present it to the action of the cutter, holding it securely until it is cut through.

925.



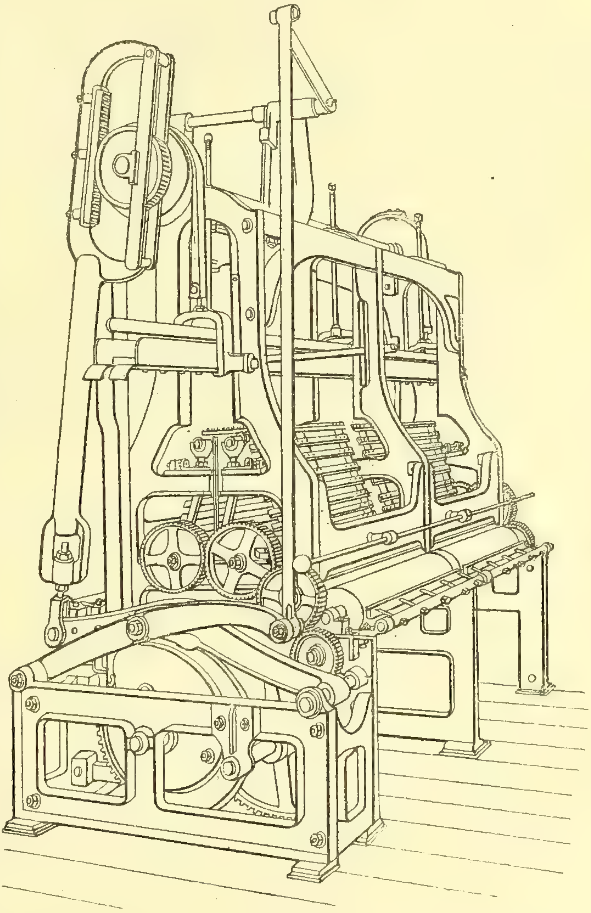
The sheets should not be driven too quickly, as by so doing, danger is incurred of tearing and breaking the fibre instead of splitting it properly. As to what constitutes a proper speed there is a difference of opinion, but good authorities agree upon the following as affording satisfactory results: About 6 lifts of the head and 20 rev. of the sheet a minute, the finishing-tool containing 8 pins an in., and two rows for six-tool machine, for coarse long-line flax; 5 lifts of the head, 15 rev. sheet a minute, 14 pins an in., two rows for nine-tool machine, for medium long-line; 6 lifts of head, 20 rev. sheet, finishing-tool 30 pins an in., two rows for twelve-tool machine, for medium cut-line; 3 lifts of head, 10 rev. sheet, finishing-tool 50 pins an in., two rows for twelve-tool machine, for very fine cut-line.

The hackling-machine is a costly article (250*l.*–300*l.*) in the first instance, and expensive to maintain, the wear and tear of the working parts being great, and their frequent renewal a necessity. Fig. 926 shows Cunningham's machine in perspective; it is made by the firm previously named, and is esteemed in the trade. The "manning" of the machine-room is a comparatively small charge, the labour employed being chiefly that of boys and youths, and consisting of tipplers, fillers, and changers, whose wages are 1*s.*–1*s.* 3*d.* a day.

Dressing and Sorting.—As the flax comes from the hackling-machine, it is held best for it to be drawn through a coarse hackle (a "ten"), broken, and next cleaned over a fine one called a "switch." Highly skilled and experienced men ought to be, and are usually, employed in this task as the assortment of the flax into its different qualities, performed by them, requires experience, intelligence, and quickness of perception to execute it satisfactorily. The coarser varieties of flax are put into the hands of apprentices, girls, and women, as their intrinsic value would not justify the employment of the more costly labour upon them. This is all done by hand. The old and laborious system of hand-dressing, which required a long training to acquire skill therein, has been so far superseded by machine-hackling that it is now rarely employed. One machine produces as much dressed flax as 20 hand-workers; four "roughers" are required to supply one machine, and about 6 or 7 sorters to dress the "longs."

When the piece has been properly levelled and dressed, it is ready to be transferred to the table, to the bunch in process of formation which in its various qualities it most resembles, where it is carefully placed in such a manner as not to disturb the order in which the fibres lie. But this is done only after it has been what is called "lapped," in which a portion of the end is thrown round the end of the piece in the form of a lap. The pieces are laid so as to overlap each other, but only in such a manner as to contribute to the building up of a square and firm bunch. Each bunch weighs about 20 lb., and is generally tied with four bands; but in cases where the finer qualities are being treated, they are sometimes carefully put into boxes before being received into the store, where the flax may have to remain weeks, months, and in exceptional cases even a year or two, during which time it ought to be preserved unruffled.

926.



A careful assortment of the qualities of the flax is exceedingly important, as upon the skill with which this has been done, and the care with which it is subsequently preserved from becoming intermixed, depend satisfactory results in the spinning process. The points to be observed in sorting are fineness, length, strength, colour, and cleanliness; and these are required to be noted during the half-minute or so that a piece is in the hands of the operator undergoing dressing. It is exceedingly difficult to secure a perfect assortment of flax into its different qualities, because whatever principle is adopted as the basis, it is sure to fail in one point or other to give a good classification. If more than one system be employed, the number of sorts becomes unmanageable, and leads to confusion, whilst both warp and weft yarns are apt to be injured by the presence of fibre that ought to have been in the opposite class.

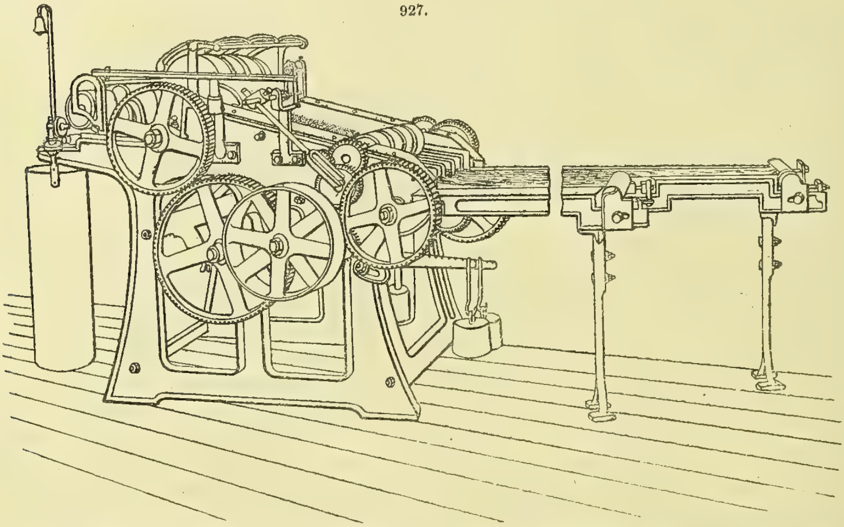
The most satisfactory arrangement of the various processes is to have the roughing, machining, and sorting in separate apartments, each under the care of an overlooker responsible for the proper performance of the work committed to his charge. The roughing-room should be in immediate proximity to the rough-flax store on one hand and to the machine-room on the other. The sorting-room should be provided with plenty of light, a northern aspect being the best, and efficient ventilation. It should also be near the machine-room on one side, and the dressed flax and tow-stores on the other. This arrangement entails less expense in handling, and less liability of spoiling the work or making waste through carelessness. This plan can, however, only be adopted in large establishments. In small ones, it is generally most economical to have these processes upon one floor, under the observation of a principal overlooker, but so arranged that the work shall proceed with the least interruption and handling, and in the most direct way.

Preparing.—On the efficiency and skill with which the "preparing" is performed, the best results almost entirely depend. Here the advantages of the preceding operations, however well managed, can be easily neutralized; whilst defective or negligent work at this stage cannot have its consequences eliminated subsequently. With practical knowledge and conscientious care at this point, from good material the very best results may be anticipated, whilst from an indifferent quality a product may be obtained that could not justly be expected.

The flax, dressed and sorted as previously described, is brought to the "spreading-frame," which is the first machine through which it passes in the preparation. Its function is analogous to that of the carding-engine in cotton manufacture, as the material in its passage through it is first converted into a sliver. It is a machine of about 10 ft. in length from back to front, and about 4–5 ft.

in width and height. A plain iron roller, called the "boss-roller," which may be 2–4 in. in diam., extends across the frame about 3½ ft. above the floor, being supported by journals resting in bearings in the frame. In its front is a cast-iron plate with diagonal slits, called the "doubling-plate." These slits are equal in number to the rows of gills in each head of fallers. These gills and fallers are precisely similar in construction, and have the same function, as those described and illustrated in the article on Jute Manufacture, to which the reader is referred (see p. 1180–1). Upon the boss-roller, are pressing-rollers, composed of wood, and in shape corresponding to the bosses of the preceding roller. Two of these wood bosses are fixed upon one axle, and work in pairs. They are adjusted at the angle which will deliver the sliver to the doubling-plate in the best form. Upon the space between these bosses, are suspended hooks, to which springs adjustable by thumb-screws are attached, by which the force wherewith the presser-rollers bear upon the boss-roller can be graduated according to requirement. The back- or feed-rollers of the spread-board are set close behind the travelling gills, and at such a height as to allow the pins of the gills, when being lifted from the lower screws, to penetrate the fibre. Behind the feed-rollers, is a revolving leather apron; and between them, a conductor-plate. Fig. 927 represents the spreading-frame, as made by Fairbairn, Kennedy and Naylor, of Leeds.

927.



The operation is as follows: the attendant girl, called a "spreader," takes the pieces from the sorter's bunch, and divides them into as many portions as are consistent with the nature of the work in process—which may require light, medium, or heavy spreading, and then proceeds to lay them upon the revolving apron as evenly as possible, with the "top-end" nearest the feed-rollers, taking especial care not to toss the fibres, nor disturb their parallel arrangement. In this manner, the fibre is fed upon the revolving apron in an even and straight line down its length. Care is taken that each piece shall fall a little behind the preceding one, so that the feed thus formed may not enter the gills too heavy, and yield too thick a sliver. The flax, after being spread, is delivered by the revolving sheets into the conductors, thence passing through the feed-rollers to the gills, which travel slightly more rapidly than the feed-rollers revolve. The fibre is next delivered over brass guide-plates to the boss- and pressing-rollers, which have a much quicker revolution than the feed-rollers. By these, its foremost and longest portions are drawn quickly away in succession in a light, continuous, ribbon-like form, constituting the sliver. In this form, it is conducted to the doubling-plate, and passed through a diagonal slit under the plate, where it is joined by the others, except one from the same head, all passing together up through the last slit, where it unites with the outside sliver which has not been through a slit, and, in this combined form, the whole pass through the delivery-rollers and are deposited in long cylindrical cans, termed "sliver-cans." Upon the end of the delivery-roller, is fixed a small worm, which gears into a wheel, and this into another, called the "bell-wheel," one revolution of which rings a bell, indicating that a given length has been deposited in the can, which is then removed by the attendant, who immediately puts an empty one in its place. The tenuity of the sliver depends upon the lightness or thin spreading of the material upon the feed-aprons, and upon the draft of the boss-roller. These points are arranged according to requirement, and this having been accomplished, the weight of the sliver, or the number of yards per lb., can be perfectly controlled, being simply a matter of calculation.

The full cans from the spread-board are carefully weighed, a given number forming a set, which are to be subsequently doubled again into one sliver, for the purpose of eliminating any inequalities that may exist. In the next operation, the sliver from the spread-board passes to the first drawing- or "set-frame," so called from the cans containing the sliver being made into "sets" of a certain number, depending upon the number of rows of gills in the "head." These are usually 6 or 8, and as two slivers are put through each row, the number of cans required to form the set is 12 or 16. The set requires to be of a certain weight, and in order to obtain this with accuracy, the sliver-cans are made uniform in weight; this being known, they are weighed when full, and the nett weight of sliver in each is carefully marked upon the outside with chalk. The cans from each spread-board are marked with the number of the machine from which their contents have come, and are kept by themselves. When a set is required for one of the drawing-machines, the boy whose duty it is to provide it, selects from the stock of cans those whose weights will exactly make the total required. By this means, any irregularities that may exist in the sliver, owing to variation in feeding the machine, or other causes, are eliminated.

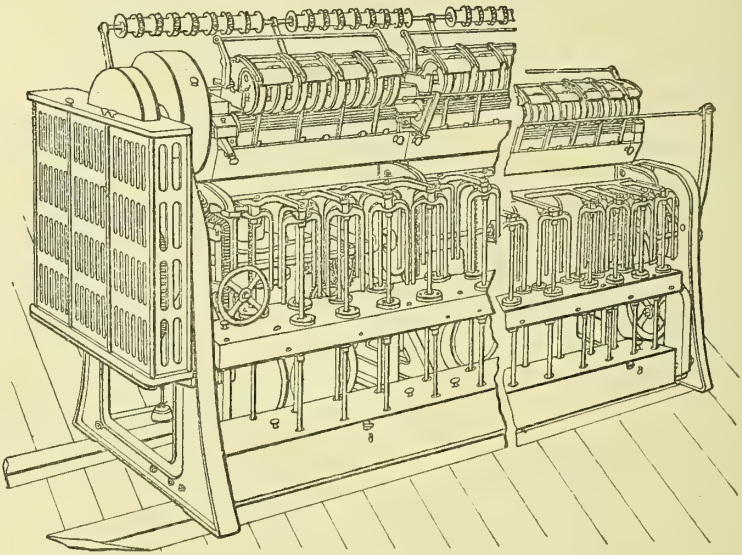
The drawing-frame is very similar in its construction to the spread-board, but is without the revolving apron or leathers, the place of these being supplied by rail and guide-pulleys, as the ribbon-like form of the sliver now requires. The feed-rollers and travelling gills are the same as in the preceding machine, except that the latter are arranged with their pins in a vertical position, whereas in the former, they were slightly inclined in the direction of their traverse. All the parts are finer and proportionately smaller, the work required from them not being so heavy as in the preceding machine.

The function of the drawing-, or 1st set-frame, is to double the sliver from the spread-board, further attenuate it by drawing, and enable the weights to be so regulated as to conduce most perfectly to the attainment of the desired end. In order that this may not be marred, close attention is required to all the details, it being especially requisite that care should be taken not to let any "single" pass through. "Single" is the term applied to the sliver, when, from breakage, or exhaustion of the contents of one can, the remaining sliver of the pair continues to pass on alone, so that on emerging at the front, it has only half the required substance and strength. Should this not be detected, it would seriously damage the yarn at the end. When discovered, it is pulled out of the can, or, if it has reached the roving-frame, and gone upon the bobbin, it is withdrawn from that. Those engaged in tending the machines can easily tell when the faulty portion has been drawn off, by the thickness of the sliver between their fingers. The "single" portion becomes waste, and is put into a receptacle provided for it. There are several causes which operate to produce single, besides the above, and in some cases, considerable damage to the gill-pins is also a consequence. Occasionally a fibre or two will lap around the pressing-rollers, and drag others with it, until in a very short time the whole sliver has been turned from its proper course, and wound round the roller, its fellow sliver going forward alone. Sometimes the lap becomes so thick that, when formed on the inside feed-roller, the gill-pins in rising penetrate it, the consequence being that they are strained or broken, which entails considerable loss, owing to the stoppage of the machine and the cost of repairs. Gills are frequently damaged from other causes, which cannot be detailed here. Single, if it has passed the roving-frame, and got upon the bobbin, may almost always be detected through the material upon the bobbin being much softer than the average, owing to its containing much less weight. There is generally attached to each machine an appliance whereby it can be stopped on the occurrence of any unusual strain upon the parts, and if maintained in good working order, this is usually sufficient to prevent the occurrence of much injury.

In each "system," or set of machines that work in succession to one another, there is the spread-board, and 1st, 2nd, and 3rd, and where a great amount of doubling is required, a 4th drawing-frame. In some cases, the last is omitted, and the sliver is instead put a second time through the 2nd, or other doubling-frame, as may be deemed suitable for the purpose. The latter plan, however, is only adopted when absolutely necessary, because it interferes with the orderly supply of sliver to the succeeding machines, the speed of which it is necessary to reduce, or otherwise allow them to stop. Other means are accelerating the speed of the drawing-frame, thus put to do double work; or increasing the draft; or a combination of these. None, however, is so satisfactory as the inclusion of a 4th drawing-frame. These last call for no detailed description, being merely repetitions of the others in every respect, except that the working parts are finer and smaller in proportion.

Roving.—When the material has passed the series of drawing-frames, in which it has been thoroughly opened, cleaned, doubled, and attenuated as sliver, without being twisted, it arrives at the last machine in the preparatory stage of its progress. This is the roving-frame, Fig. 928, a long rectangular machine, similar in its construction to the preceding, so far as concerns the possession of a series of "heads" of gills, traversed from back to front upon spiral screws, but differing in delivering the elongated sliver to revolving spindles, which twist and wind it upon the bobbins with which they are furnished. The roving-frame contains 4–7 heads, each having 8–12 rows of gills. The slivers from the last drawing-frame are passed singly—the doubling being finished—over the rows of gills, and are again further "drafted" in the process. The sliver has now become so attenuated that it is necessary to impart a little twist to it, so as to secure its coherence. This is accomplished by means of the spindle and flier, this machine being one of those belonging to the numerous group found in nearly all the textile industries, and known as "bobbin- and fly-frames." The mechanism of these having been illustrated and fully described in the article on Jute Manufactures (p. 1182, Fig. 869), the reader is referred thereto for further particulars. After having gone through the gills and delivery-rollers, the attenuated sliver passes downwards through the neck of the flier, next through a groove in the leg, and then through the eye to the barrel of the bobbin. Generally the arrangement is that the spindle shall "lead," and the bobbin "follow": that is, that the revolutions of the bobbin shall be so many less than those of the spindle, so as to enable it to wind up the roving as it is delivered from the rollers. When the spindles are filled with a set or "doff" of bobbins, as a full complement is called, the barrels are bare, and consequently at their least circumference, and will take up the rove at the slowest rate. In starting, therefore, they require to lag more behind their "leader" than at any other point. As the circumference of the barrel increases with every layer of rove deposited upon it, the rove would be taken up more quickly every time, and would consequently be first drafted much finer, and then broken, were the speeds of the flier and the bobbin constant at the proportionate rate at which work was commenced. But this result is obviated by the provision of an appliance by which the proportionate speeds are changed, the bobbin being accelerated as the circumference of its winding-surface enlarges by the addition of successive layers of roving. This is called the differential driving-gear, explained in the article on Jute, before referred to. Sometimes "cones" are employed to obtain the same result. When the latter are adopted, the upper cone is connected with the gearing of the frame, and its speed is constant. The driven cone is of the same shape as the driver, but is fixed in the reverse way: that is, the smallest diameter of one is set opposite the largest diameter of the other. The connection is by means of a strap, and this being traversed along the cones, gives a constantly varying rate of revolution to the driven cone, which is so adjusted as to accelerate the speed of the bobbin, until, when full, it very nearly equals that of the spindle. The belt is shifted on the cones about ¼ in., or other necessary distance, every time the traverse-rail in rising or falling arrives at the end of its course, and a fresh layer of rove has been placed upon the bobbin. After doffing the set of bobbins, and filling the frame anew, the differential driving-gear is readjusted, so as to commence again at correct speed.

928.



The temperature of the rooms in which preparing is carried on should be preserved as uniform as possible, not to fall below 15½° (60° F.), nor exceed 21° (70° F.). This is not difficult to accomplish in a well-found mill, and tends greatly to the production of satisfactory work. An excess of heat or cold, dryness or moisture, causes the sliver to lap round the rollers, the result being unsatisfactory work, diminished production, and increased waste. When, owing to atmospheric conditions, the air of the rooms is heavy with moisture, it should be warmed and dried by the introduction of steam into the warming pipes, regulated until normal conditions are restored. In the sharp, dry frosts of winter, or during the prevalence of dry east winds, the same tendency of the fibre to lap is often seen; in either case, the evil will be obviated by having a few jets in a steam-pipe and allowing the steam to blow into the room, when the moist particles are quickly absorbed by the dry atmosphere, and the fibre in process again becomes soft and pliable, following its proper course through the machinery. Where there is no provision for introducing steam in this manner, it will be convenient to sprinkle water upon the floor, in which case, hot water is best. Care must always be taken not to carry these proceedings to excess, and cause the atmosphere of the room to condense its moisture upon the machinery and walls, giving to everything a damp, clammy feel. Drafts or currents of air should also be carefully avoided, as provocative of the same mischief, whilst good ventilation should be provided. The rooms should also be furnished with sun-blinds to the windows, as excessive heat from direct sun-rays will also produce a similar effect.

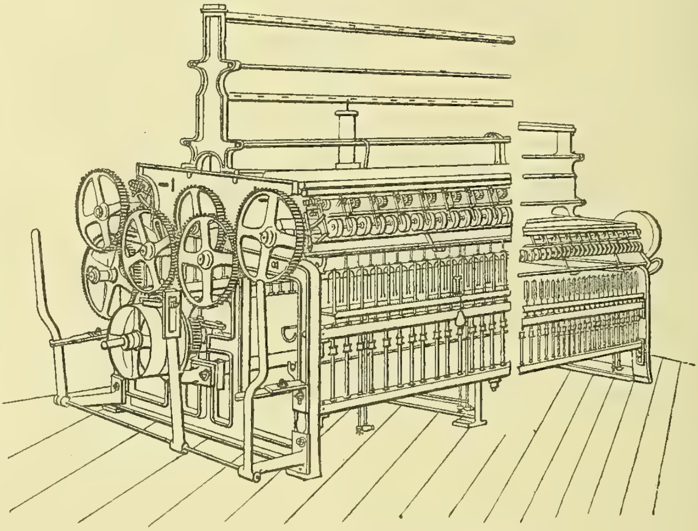
As in the management of all machinery, strict supervision should be maintained. Every part should be promptly supplied when broken or worn out, and the small essentials known as "mill furnishings," such as strapping, laces, banding, brushes, oilcans, oil, &c., whilst strictly dealt out, should never be denied in sufficient quantity. Though the aggregate charge resulting from this provision is considerable, economy in this would be at the cost of a more than corresponding depreciation arising from the extra wear and tear of the machinery, leaving out of consideration the inferior quality of the production. Thorough cleanliness should be insisted upon in every department. The machinery should be overhauled and cleansed at stated intervals. The reward for attention to these matters will be a large production, thereby diminishing the cost; a high quality, which will secure good prices in the market; a contented class of workpeople, earning good wages, and therefore not ready to quarrel with their employment; and last, but not least, a satisfactory balance-sheet at stock-taking.

Tow Preparation.—From the moment flax begins to undergo preparation for spinning and weaving, or any other divergent end, there is produced more or less "tow," or short broken fibre. This is principally obtained in the scutching, machining, and dressing processes, to which is generally added the sliver-waste produced in the more advanced processes. That obtained from scutch-mills has usually had the husk of the plant shaken from it, and is then sent to market as "scutching-tow," commanding only a few shillings a cwt. This is sold to coarse-tow spinners, who usually pass the material through a "shaker," by which it is more perfectly cleansed from the husk, after which, it is put through the "breaker-card." In other cases, it is preferred to get it rescutched over finer and lighter "handles" than those over which the flax was first put. The cost of performing this operation is about 4*s.* a cwt., whilst the produce obtained will not be more than ¼ of the quantity submitted to the process. Loss of weight and expense of cleaning bring up the cost to something over 1*l.* a cwt. Sometimes this class of tow is worked alone; in other cases, it is mixed with "milled tows," or those obtained from the processes of hackling, machining, and dressing in the flax-mill. The tow is first passed through a coarse card, and next through a finisher-card, after which it enters upon its course of preparation for being made into tow-yarn, which does not differ materially from that of line flax.

The "breaker-card" is a powerful engine with a large cast-iron cylinder, 3–5 ft. diam., and 4–8 ft. across the face. This is mounted upon a strong frame, and is almost surrounded by a series of smaller rollers of the same breadth, called "workers" and "strippers," all of which are covered or clothed with steel pins, of a size suited for the special character of the work they have to perform. A "feeding-sheet" or revolving apron is attached to the back, upon which the tow is evenly spread and slowly carried to the feed-rollers, by which it is delivered to the revolving cylinder. These rollers are about 3 in. diam., and have a surface movement of about 18–24 in. a minute. The direction of the revolution of the cylinder, at the point where it receives the tow, is downwards; and it consequently strikes the tow with great force in that direction. The pins with which it is clothed are generally about ⅞ in. long, and are inclined in the direction of its revolution. These pins are set in "lags" or staves of wood, secured to the cylinder by screws. They are ⅜–⅝ in. thick, 1 in. broad, and 24 in. long. The pins therefore protrude through them about ⅜–¼ in. The feed-rollers are also clothed with pins, those of the bottom one being slightly curved upward, as they present the tow to the pins of the cylinder, and therefore prevent the latter dragging in the material at too quick a rate. This resistance of the feed-roller secures a maximum of effective action, splitting and combing, on the part of the cylinder. It tends, however, to embed the fibre in its pins, and would, from this cause, soon destroy its efficiency, were provision not made to keep it clear. This is accomplished by the introduction of a third or "feed-stripper" roller, placed beneath, but sufficiently near for its pins, which are inclined towards the large cylinder, to strip the feed-roller by its greater speed. In its turn, it is stripped by the cylinder, whose surface velocity is again much greater. The cylinder, having received its full complement of tow, carries it forward to the "first worker," the second roller in the course of its revolution, which has about the same dimensions as the feed-stripper. This roller revolves at a slow rate, in a direction opposite to that of the cylinder, and as its pins are inclined so as to receive and retain the fibre from the cylinder, the latter is cleared, the material being split to a further extent by the action of the pins.

Revolving at a higher speed, and in close proximity to the first worker, is the first roller in the series which the cylinder passes after leaving the feed-rollers; this is the "first stripper," whose function is to strip the worker, and return the material to the cylinder. No splitting or cutting of the fibre takes place in this case, the duty of the stripper being merely to return the fibre from the worker to the cylinder. The number of workers and strippers is dependent upon the size of the cylinder, which will permit more or less to be arranged around its circumference. This again depends upon the requirement of the work, or what is called the "fineness of the card." When the tow has passed the series of workers and strippers, it is received by a large roller, called the "first doffer," clothed similarly to the workers, but not accompanied by a stripper-roller. It brings the tow to the front of the machine, at which position it is stripped from it, by the rapid oscillating stripper-knife in its front, in the form of a sheet; this is next divided into three portions, and each is passed between a pair of rollers, which calender and lay the fibre in the form of a sliver. Beneath the first doffer-roller, are one or two more of the same sort, having the same function, and stripped in the same manner, as the first. The slivers from all the doffers are received into a large can, and carried away to another machine, by which they are combined into the form of a lap, to fit them for the "second carding."

929.



The laps from the first carding are then placed in the second, or finisher-card at the back, in the position occupied by the feed-apron of the first machine, but which does not appear in this case. The finisher-card is in principle precisely like the first, differing merely in details. Its pins are finer and shorter, and its rollers more numerous and smaller, by which means, the tow is subjected to more treatment than in the first instance.

In the treatment of superior tows, a combined machine, called the "breaker- and finisher-card," is often employed, in which one operation suffices to do all that is required. In this instance, the tow is evenly fed upon the revolving apron, passes through, and is delivered in an even sheet, which is divided into a number of slivers, one for each of the front conductors. They are next passed through the conductors of the bottom doffer, over a polished cast-iron plate, called the "sliver-plate," and into the back conductors of a "rotary-card drawing-head," which is attached to the machine, and so-called because the traverse of the gills is accomplished by rather different means than the spiral shafts of the ordinary drawing-frame. The sliver then passes through a very coarse open gill on a short draft, which prepares it for the first drawing-frame. The rotary head has one, two, or three rows of gills, according to requirement. Altogether, it is regarded by many persons as a questionable improvement, and its application is far from being general. When it is absent, the sliver is carried direct to a drawing-frame, in which it is worked up into sets.

Tow-carding engines should be carefully set, so as to stand perfectly level. Proper lubrication ought never to be neglected, and the drums and driving-pulleys should be as large as convenient, in order to give the fullest purchase, and so secure the most even and economical driving, without which the sliver will suffer in quality, and make inferior yarn.

Spinning.—Spinning is the concluding process of this division. In it, the material which has come through the successive stages is converted into yarn, and forms in this condition a merchantable article. In many cases, flax-spinning establishments have weaving branches in connection with them, in which case, their production of yarn may be consumed upon the premises. In others, it is sent upon the market, and forms the supply which is drawn upon by establishments at which weaving only is carried on.

The spinning-machine, Fig. 929, like the roving-frame, is a "bobbin-and-fly" frame, and is made of such "pitch" or dimensions as the circumstances of individual spinners may lead them to select. They generally contain 200–300 spindles. In arranging the spinning-room, care should be exercised to secure a sufficiency of space, so that no part will be crowded, nor the necessary movements of the operatives impeded. Should the latter be the case, it is certain that some duties will be neglected, to the injury of the establishment. Light and ventilation ought to be provided to a full extent: the former to enable the spinners to see with ease whenever a thread has broken, or any other defect occurred; the latter, on account of the danger to the health of the operatives if they are permitted to work in foul air saturated with vapour arising from the great quantity of hot water employed in the wet process of flax-spinning.

A flax-spinning machine consists of a strong rectangular frame, about 3 ft. broad by a length proportionate to the number of spindles it contains. The latter are mounted in two rails, the lower one carrying the spindle-footsteps into which the base or foot of the spindle is inserted and revolves, the upper one containing the "bolster" or collar in which the "neck" of the spindle is enclosed, and by which it is maintained in a vertical position. Each spindle carries a flier on the top, and is furnished with a small pulley called a "wharve." Longitudinally through the centre of the machine, extends a tin cylinder; on the extremity of the shaft forming its axle, are fixed the driving-pulleys. Cotton driving-bands connect the cylinder and spindles, by which, motion is transmitted from one to the other. A traverse-rail, or "builder," having circular holes through which the spindles pass, is fitted to the machine in such a manner as to automatically rise and fall when the machine is at work. The bobbins are placed upon the spindles, and drop down until they rest upon the traverse-rail, which when at work carries them up and down to receive the successive layers of rove from the fliers. The fliers are next screwed upon the tops. The latter, having been several times already brought under the notice of the reader, need no further description. There is no independent driving power required for the bobbin, the drag of the thread being sufficient to pull the bobbin round; it lingers sufficiently behind, however, to take up the yarn as it comes from the rollers and is twisted by the revolving spindle. To retard the motion of the bobbin so much as is requisite to make it perform the function of winding on the thread with firmness, light bands are attached to the back of the traverse-rail behind the spindles, passed around the base of the bobbin, brought over the front of the traverse-rail, and allowed to hang down, having a small weight attached to the end. These are called "drag-bands." The friction or power exerted by these bands is varied by means of a comb upon the front of the traverse-rail. When the spinning is commenced, and the bobbins contain scarcely any yarn, they develop comparatively little centrifugal force, and therefore require little check upon them; as they fill, this force becomes greater, and the spinner has to advance the drag-band a groove or two upon the comb, so that it will increase its contact with the base of the bobbin, and exert a greater retarding power. The correct management of the drag-band is important in flax-spinning, as it is required to be accurately adjusted, to make good yarn and keep up the ends.

Within the past few years, a "spring self-acting drag-motion" has been introduced. It dispenses with the cord and weight, and, by a simple and ingenious arrangement, makes the dragging of the bobbin automatic, and keeps the necessary tension on each thread during the time the bobbins are being filled. The appliance consists of a peculiar angle-shaped metallic rod, arranged along the front of the traverse-rail or "builder." To this rod, are attached springs, one for each bobbin, the arms of which press against the bobbin, the pressure being regulated by means of a worm and ratchet-wheel. When the counts of yarn are changed, it is merely necessary to change the ratchet-wheel instead of all the drag-weights, as in the old method, which is an expensive system in both time and labour. The spinner is also relieved of all care of watching the individual bobbins, and is therefore at liberty to pay more perfect attention to the other portions of her work, or to take charge of an increased number of spindles.

The drawing-rollers of the spinning-frame are fluted, and composed of brass, in order to prevent oxidation through the presence of water necessary in the spinning process. The pressing-rollers are preferably of box, but several other woods are occasionally used.

The sliver-bobbins from the drawing-frame being placed in the "creel" or rack, the sliver is conducted from them into the hot-water trough, in which it is saturated, and then passes between the drawing- and pressing-rollers, by the action of which, the superfluous moisture is pressed out, and the sliver attenuated to the required extent; on emerging from the "nip" of the rollers, it receives the twist from the revolving spindles, and descends through the holes in the thread-plate, whence it passes to the flier, and is wound upon the bobbin in even layers by the rising and falling of the "builder" or traverse-rail. The bobbins having been filled, the fliers are unscrewed from the spindle-top; the set of full bobbins are "doffed" (removed) and replaced by another set of empty ones; the fliers are again put in their places, and spinning is recommenced.

Reeling, Drying, and Bundling are the subsequent processes necessary to complete the preparation of the yarn for the market.

"Reeling" is the operation of running the yarn off the spinning-bobbins upon reels of 90 in.

circumference, by which means, it is divided into measured lengths. It is a very simple operation, but its prompt performance is extremely important, owing to the fact that the yarn, having been "wet-spun," must be quickly cleared from the bobbins in order to be dried. Should this be neglected for a few days, it is probable that the yarn would be injured by mildew. The stock of bobbins required to keep the spinning-machines supplied is also so large that only few mills could keep their machinery at work more than three or four hours after the reeling process has been suspended. The bobbins when doffed by the spinner are put into boxes by the frame, and are fetched thence by children, who place them in "cages"—small boxes containing as many "pins" as there are spindles in one side of the spinning-frame, on which the bobbins are placed for transmission to the reeling-room.

Formerly the reels were worked by hand, as, owing to the very frequent stoppages, the application of power was difficult and unsatisfactory. Of late years, however, from the difficulty of finding an adequate supply of reelers, means have been devised to overcome these obstacles, and reels driven by power have come very generally into use.

In reeling, the chief care ought to be to keep up the threads, so that the hanks will not be short, as, being sold by measurement as well as weight, complaints would be received from the purchaser on this ground. The length is measured by the revolutions of the reel, which are indicated through a bell-wheel driven by a worm upon the axle of the reel. When the hanks are completed, of which there are 20–24 reeled at one time, each containing 3600 yd., the reeler doffs the frame by drawing out three wooden pins from the three spokes of one rail of the fly, which then drops down, and allows the yarn to become slack, and be easily stripped from the reel. Care must be exercised that they shall not be stained with oil in the stripping or other process, as it depreciates the value considerably, through the difficulty of clearing away the traces of this in bleaching or other subsequent treatment.

It is in the reel that the yarn is measured, and it will therefore be proper in this connection to introduce the yarn table which is used in the trade. The standard is 1 lb. of 16 oz. The particulars are as follows:—

LINEN YARN TABLE.

2½ yd. (one rev. of reel) = 1 thread
300 „ or 120 threads = 1 lea or cut
3,600 „ „ 12 cuts = 1 hank
60,000 „ „ 16⅔ hanks = 1 bundle
72,000 „ „ 20 „ = 1 reel
180,000 „ „ 50 „ = 1 3-bundle bunch
360,000 „ „ 100 „ = 1 6- „ „
720,000 „ „ 200 „ = 1 12- „ „

In speaking of the fineness of flax yarns, 1 lea-yarn would mean that there were 300 yd. in 1 lb., and 100 lea would imply 100 × 300 = 30,000 yd., and similarly of other numbers of leas. There is a system of "short-reel measurement," which is used mainly for convenience.

Flax yarns are generally dried over the boilers of the establishment, in apartments specially prepared to utilize the heat which is thrown off. The hanks are suspended upon drying-poles, which are made smooth, and painted, so that the yarn shall not be scratched and torn on splinters. The room in which the drying takes place requires to be well ventilated, so that the moist air can easily be drawn off. In some cases, it is desirable to use a "drying-machine," invented for the purpose, and which has been found very efficacious.

After being sufficiently dried, the yarn is next put up in bundles, and made into bunches of any desired size, containing 1–12 bundles, according to the lea, and the requirement of the manufacturer.

Weaving and its Preparation.—There is little to distinguish the weaving branch of the linen trade from that of the other textile industries (see Cotton Manufactures, Jute Manufactures). The yarn in the first instance, however, is carefully boiled and washed, by which, much of the natural gum upon the fibre is dissolved, and it is rendered more pliable. If the fabrics are intended to be white, the yarn at this stage is bleached (see Bleaching, p. 515), and if coloured, dyed. In both cases, it is dried after the process.

From the hank, it is next transferred to large bobbins in the winding-frame, a simple machine, not essentially different from similar ones described under other headings (see p. 768, Fig. 555). The bobbins are now transferred to the warping-mill or frame, which may be the old vertical reel-frame, or the more modern machine which puts the yarn upon a beam for the sizing-frame (see pp. 769–70, Figs. 556–7). In the sizing-frame, which is not materially different from that employed in the cotton trade (see pp. 770–7, Figs. 558–62), from which it has been adapted, the warp passes through a sizing-mixture, whose chief ingredient is Irish Moss (see Drugs, p. 814). It is dried by passing over steam-heated cylinders, contained in the same frame, and is delivered upon the loom-beam. Passing from here, it has the heddles attached in the usual manner—drawing-, tying-, or twisting-in, according to the description of the work. The warp is then ready for the next process.

Weft yarns have also to undergo a course of preparation, though shorter than the above. As it is identical with that described in Jute Manufactures (see p. 1185), it need not again be introduced.

The power-loom is now very extensively employed in weaving linen. For a considerable time, many difficulties were experienced in adapting it to this purpose, but, by perseverance, these were eventually overcome. They chiefly arose from the inelastic character of the yarn, which would not yield or stretch to the requisite distance to allow of the formation of a "shed," or opening of the warp for the passage of the shuttle by the operation of treading, without breaking large quantities of yarn. This was overcome by the invention of the oscillating carrier-beam, over which the warp passes on its way to the heddles. When the shed of the warp is closed, one of the two rollers composing this beam is raised by means of a cam upon the driving-shaft of the loom through a connecting-rod, so as to take up a portion of the warp. When the shed requires to be open, this roller is depressed, thus affording sufficient slack in the warp for a shed to be made by the tappets, without undue strain upon the yarn. This invention overcame the chief difficulty experienced, and has led to the introduction of the power-loom, and its successful operation, in the greatest portion of the trade in this country.

The power-loom employed in weaving light linens is almost identical with that of the cotton trade (see pp. 780–6, Figs. 566–570). Heavier fabrics require a correspondingly stronger loom, but this is nearly the only difference. Fabrics which differ from plain cloths necessitate the use of various attachments, such as twilling-motions, dobbies, jacquards, &c. The jacquard sustains an important part in the linen trade, being employed extensively for the production of damasks, table-cloths, and other ornamental linen fabrics. Of these, perhaps, it may be truly said that, by its aid, Belfast has produced the most perfect specimens of the textile art that have ever been fabricated.

Statistics.—The present condition of the linen manufacture is one of considerable depression, and its future is not regarded without anxiety by those to whom its prosperity is of the deepest interest. Cotton is the most dangerous rival it has to encounter, and the progress of the latter during the present century has to some extent been at the expense of linen. During the American civil war, and the consequent scarcity of cotton, linen fabrics were largely substituted, and the industry prospered greatly. With the return to normal conditions, and the prospect of a very low range of prices in the cotton trade, it is to be feared that the competition in the future will be still more severe, and to the disadvantage of the linen trade. But whatever may be the result of this, the products of the latter industry will always have a place, from the impossibility of a suitable substitute being found.

The following figures from the latest Returns upon the subject, and corresponding figures from the last preceding Returns, will be of interest.

Flax Factories in Great Britain and Ireland.

Countries.	No. of Factories.	Total No. of Spinning-spindles.	Total No. of Doubling-spindles.	Total No. of Power-looms.	Total No. of Persons employed.		
					Males.	Females.	Total.
England and Wales	101	190,808	28,439	4,081	4,812	10,176	14,988
Scotland	155	265,263	18,495	16,756	9,987	27,489	37,476
Ireland	144	808,695	18,048	19,611	17,036	39,306	56,342
Grand Total, 1879 ..	400	1,264,766	64,982	40,448	31,835	76,971	108,806
„ „ 1874 ..	449	1,473,800	81,335	41,980	37,931	90,528	128,459

In the above figures, no note is taken of the number of persons employed in cultivating the raw material, and handling it in the earliest stages; neither is there any cognizance of those engaged in the domestic branch of the industry, the Return covering only the establishments subject to inspection under the Factory Acts. A great portion of the decline exhibited in the five years is attributable to the decay of the English branch of the trade, which has retrograded fully 33 per cent. In Scotland, there is also a slight reduction; but in Ireland, there is scarcely any change.

Bibliography.—A. J. Warden, 'The Linen Trade' (1864); A. Renouard, 'Études sur le Travail des Lins' (Paris); 'Textile Manufacturer' (Manchester: 1874–); Flax Supply Association's Reports (Belfast: annual).

(See Cotton Manufactures; Fibrous Substances—*Linum usitatissimum*; Jute Manufactures; Lace.)

R. M.

MANURES (Fr., *Engrais*; Ger., *Dünger*).

Every plant requires to be fed with certain substances, in order to attain perfection. The proportion of each substance needed by different plants varies considerably; but the substances themselves are the same in kind in almost every case, and consist principally of nitrogen, potash, phosphoric acid, lime, sulphur, soda, magnesia, chlorine, and silica. A productive soil contains all these elements in sufficient abundance, and will go on bearing crops incessantly, provided that all the plants which grow upon it be returned to it, either in a rotten natural condition, or as the excreta and remains of the animals feeding upon them. Further, it is well known that in so-called "new countries," it is possible to grow and remove crops from the same soil for many years in succession, without artificial aid, a fact which is due to the presence in the "virgin soil" of more than enough of the various or principal elements for immediate needs. But when this store has been exhausted by constant cropping, the plants become at first sickly, and, after a time, altogether refuse to grow. Then arises a necessity for enriching the soil by the addition of the ingredients in which it is wanting. This operation is known as "manuring"; while the materials thus supplied are called "manures." The "rotation" system of cropping, based upon the difference in proportion of the various elements required by certain crops, is very judicious; but it cannot be made to obviate the necessity for adopting artificial measures for maintaining the fertility of the soil. In the present condition of agricultural science, no attempt is made to supply a manure containing all the ingredients required by the crop to be grown, nor, except in rare instances, is an analysis made of the soil, in order to determine in what element it is deficient. The farming community are generally content to apply the article which the manufacturer chooses to send them, looking rather to its price than to its efficacy, and manifesting satisfaction according to the degree of its odour.

Manures may be generally divided into two kinds, natural and artificial.

Natural Manures.—Natural manures are farm-yard dung, sewage, seaweed, soot, nitrate of soda, and Stassfurt salts; these may be applied to the land without any previous preparation. Besides these, there are other natural products, of great value in agriculture, which, used in a raw state, are not in such a fit condition to be assimilated by the plant as after undergoing the treatment presently to be described. Principally, they are bones, fish, flesh, blood, and guanos. The preparation of "poudrette," or sewage treated with sulphuric acid, and dried, will be described hereafter.

Bones.—Though very slow in undergoing decomposition, bones are a most valuable manure, especially on light soils. They contain about 2–4 per cent. of nitrogen, and 50–60 per cent. of phosphates. They are seldom applied without having been first boiled to eliminate the fat, which may be done in ordinary coppers of large size. When it is desired to extract their gelatine, for glue-making and similar purposes, the boiling is effected under pressure (see Bones, p. 521). To hasten the fertilizing action of bones, they are almost always ground in a mill, after having become sufficiently dry from the boiling operation. The finer their state, the more rapidly will the crop be benefited by their application. One of the best forms of mill for reducing bones is that shown in Fig. 930. This is a powerful and compact machine, with a cast-iron frame and foundation-plate, and when attached to a 10-H.P. steam-engine, or a water-wheel, it should crush and dress 15–20 tons daily. It weighs 7¼ tons, and the fly-wheel should make about 145 rev. a minute. It has two pairs of rollers, with cutters (made of cast-iron, and case-hardened) for crushing the bones, a revolving riddle for separating them into "rough," "half-inch," and "dust" or "quarter-inch," and a friction-sheave for preventing accidents to the cutters. Such a mill should cost approximately 250*l*.

930.

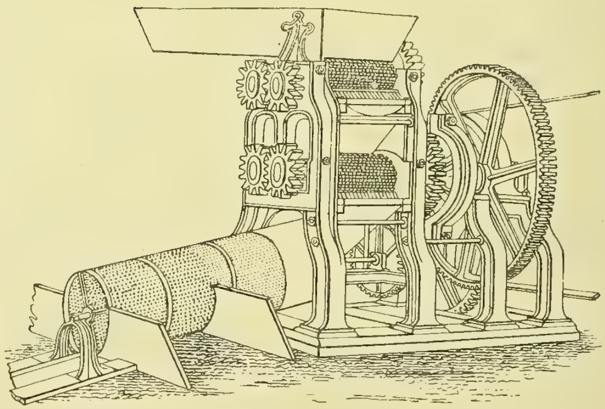
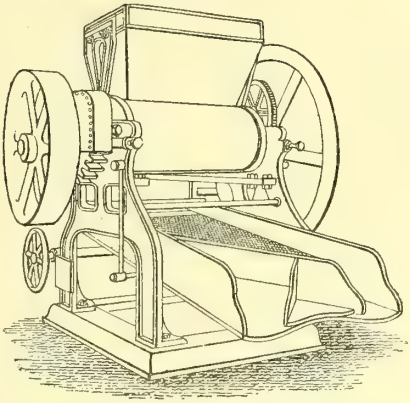


Fig. 931 shows what is known as a "dust bone-mill," consisting of a strong cast-iron frame, and two rollers furnished with steel cutters or saws, through which the bones, already ground by the mill just described, are passed, and thus reduced to dust. It requires 6-H.P.; weighs 26 cwt.; works at a speed of 240 rev. a minute; turns out 6 tons daily; and costs about 100*l*.

Occasionally, the ground bones are dissolved in sulphuric acid before use. This no doubt renders the phosphates more readily soluble, and available for the plant; but there is so much difficulty in drying the bones afterwards, that a large amount of free sulphuric acid exists in the mass, and destroys the sacks in which the manure is transported. There is also inconvenience in drilling-in the material with the seed, as is often done with dry manures. As an ingredient in other manures, however, e. g. "bone-superphosphates," &c., bones play an important part, and their presence in a superphosphate adds greatly to its value.

Fish.—Fish and fishery-offal are valuable fertilizers, rich both in phosphates and in nitrogen. In the Eastern Counties, and some other spots round the British coasts, they are sometimes applied in a raw state, when it is impossible to find a ready market for them as human food. They are often treated with sulphuric acid, in large leaden tanks, after having been pressed to extract the oil, which is, in itself, a valuable product, and whose presence would greatly neutralize the effect of the acid. In this country, very little care is bestowed on the preparation of fish-manures, and their quality varies suspiciously; but the Norwegians manufacture an excellent fish-guano, containing 25–30 per cent. of phosphate of lime, and over 7 per cent. of nitrogen. The guano-factories at Lerosen, Sanöen, and Lyngvœr produced 23,650 sacks (of 2 cwt.) of fish-guano in 1875, 23,061 in 1876, 22,561 in 1877, and 21,860 in 1878.

931.



The Americans are awaking to the value of fish-manures, and on many parts of the eastern coast of the United States, factories have been erected for the utilization of the shoals of menhaden, a fish of the herring family, which frequent those shores between April and November. In 1873, there were 62 factories at work on the coasts of New York and New England, catching at the rate of 1,193,100 barrels of fish, yielding 2,214,800 gal. of oil, and 36,299 tons of guano. Since then, the industry has much increased, particularly in N.-E. Long Island. The first step after catching the fish is the expression of its oil, which process will be described under Oils. The oil and moisture having been removed, the refuse fish is taken to the "scrap-house," and is known as "green scrap." In 24–48 hours, fermentation sets in, producing a darker shade, by the escape of ammonia; the material is then called "old scrap." In this state, it is transferred to a drying-room, where it is first subjected to a "picking" process, which consists in passing it through a cylinder armed with teeth revolving between set teeth, by which the whole mass is rendered uniformly fine. It is then dried, either in the sun, or by artificial heat. By the former plan, it is spread upon a sloping "platform," and constantly stirred by a wooden harrow, being finally gathered into a large heap, called the "cure," into which perforated pipes are inserted for conducting away any heat that may be developed. After about 4 turnings, it is cool enough for subsequent treatment. In wet weather, "platform curing" is replaced by artificial heat, which is a quicker process, but causes 10 per cent. more loss. The driers are revolving cylinders, with shelves running spirally through them. A fire is made at the front end; the hot air from this passes beneath the cylinder to the back end, and returns through the cylinder to the chimney. The drier is fed in front, and as it revolves, the scrap is carried up by the shelves to the top, whence it falls, to be taken up again in the same way. The archimedean arrangement of the shelves gradually works the material to the outlet of the cylinder. In a 25-ft. cylinder, revolving 8 times a minute, each charge takes about ½ hour to reach the back end, by which time its moisture will have been removed, and the material made ready for the "cure." If very wet, it may require 2–5 dryings. It is evident that the finest particles of the material will be carried off by the draught. Green scrap is mostly used for platform drying; old scrap, if very wet, is spread on the platform for 12–24 hours, before being put through the driers, or it would cake into balls. The dried scrap is ground and bolted in a special mill, consisting of two cylinders with cone-shaped bearing-faces, one making 2500 rev. a minute, the other 800. Analyses of dried fish-remains show 14 per cent. of phosphate of lime and magnesia, and 12 per cent. of nitrogen. Quantities of fish-"marc," or dried fish-refuse, are imported into this country for manufacture into nitrogenous manures.

Flesh.—Dried flesh forms a highly nitrogenous manure, and bids fair to assume a place in the market. It is principally derived from the refuse obtained in preparing Liebig's "extractum carnis," samples of which have shown 11–12 per cent. of nitrogen. In this country, horse-carcases are often dissolved in sulphuric acid, and applied as a manure; but their qualities are not superlative.

Blood.—The proportion of nitrogen contained in dry blood is very considerable, reaching 15 per cent. in thoroughly dried samples; but it is so difficult to remove even a portion only of the water, that its use is restricted to narrow limits, except as an ingredient added to manufactured manures.

Guano.—It is unnecessary to repeat the meaning of the word "guano," or a description of the material known by this name; but it is important to remark that the constitution of guanos is quite as varied as that of any other mineral phosphate. The nature of a guano seems to depend principally upon the climatic conditions under which it accumulates. The dry atmosphere of the Peruvian coast favours the formation of a nitrogenous guano; whereas similar deposits in moister climates lose all their ammonia, by decomposition and evaporation, and consist principally of phosphates insoluble in water; though, when removed before much decomposition has had time to ensue, they contain also a certain amount of nitrogen.

Phosphatic guanos cannot be used in a raw state, and are employed only in the same way as coprolites, or other mineral phosphates, in the manufacture of superphosphate. They will therefore be described under that head (see p. 1259).

By far the greatest proportion of the nitrogenous guanos, and certainly all the best of them, have come from Peru, or the islands on its coast. The most valuable has been the Chincha Islands variety, containing about 13½ per cent. of nitrogen, and the same amount of phosphoric acid. This was almost entirely used in a raw state, but the deposits have long since been exhausted. Following this, came other high-class kinds, such as Ballestas, containing 12½ per cent. nitrogen, and a similar proportion of phosphoric acid; Macabee, with 11 per cent. of nitrogen, and 12½ per cent. phosphoric acid; and Guanapi, yielding 10 per cent. of nitrogen, and 14¼ per cent. of phosphoric acid. But these also are fast disappearing, and are being replaced by still lower-class articles: such are Pabillon, having nearly 9 per cent. of nitrogen, and almost 14 per cent. of phosphoric acid; Independencia Bay, with scarcely 8 per cent. of nitrogen, and 10¼ per cent. of phosphoric acid; Huanillos, 7¾ per cent. of nitrogen, but over 14 per cent. of phosphoric acid; Punta de Lobos, not reaching 6 per cent. of nitrogen, and containing nearly 18 per cent. of phosphoric acid; and some from the Lobos islands, giving little more than 3½ per cent. of nitrogen, while the phosphoric acid rises above 20 per cent. A very different species of Peruvian guano is the Angamos, which is freshly deposited, and obtainable only in small quantities. It contains almost 4 per cent. more nitrogen than even the Chincha Islands variety, with but 9 per cent. of phosphoric acid. The above figures distinctly indicate the extent to which guanos from the same country and climate differ in composition. The percentage of water varies also from 8 to 29 per cent. Most of these guanos contain a certain amount of all the elements essential in a good manure, besides the preponderating phosphoric acid and nitrogen. As much of the phosphoric acid present is combined with bases, in the form of phosphates which are insoluble in water, their effect upon the crop will be hastened by treating them with sulphuric acid, which possesses the property not only of rendering soluble much of the insoluble phosphate, but also of fixing the volatile carbonate of ammonium, and converting the uric acid present into ammonia. In applying crude guano to the soil, a considerable amount of ammonia will be evaporated and lost, unless the guano be completely covered with earth. This is prevented in a great measure by the treatment with sulphuric acid. Yet another advantage derived from dissolving the guano in sulphuric acid is that the great hygroscopic properties of the acid render the manure dry and powdery; this is especially advantageous when the sample of guano is very damp and sticky, as is generally the case. Very large quantities of guano are prepared in this way in Germany, and sold by analysis, on a basis of nitrogen equal to 9 per cent. of ammonia, and about 25 per cent. of phosphates, 20 of which are soluble.

The existence of bird-guano on the Jardinillos, a group of islands to the south of Cuba, has long been known, but only recently examined. Analyses from various portions give the following results:—Cayo Largo: N.-W., phosphoric acid, 24·02 per cent., = phosphate of lime, 52·43; W., phosphoric acid, 29·33, = phosphate of lime, 64·03; S. and S.-W., phosphoric acid, 28·98, = phosphate of lime, 63·27; Cayo Dios: (*a*) phosphoric acid, 28·83, = phosphate of lime, 62·94; (*b*) phosphoric acid, 26·53, = phosphate of lime, 57·92. The deposits are now to be worked for supplying the sugar and tobacco plantations, almost the whole of the phosphate being present in a soluble condition.

In many caves in Virginia and Texas, are found extensive deposits of bat-guano, in some instances amounting to several thousand tons. The deposits exhibit a dull-brown colour, and become finely pulverulent when dried in the air. They consist of the excrement of bats, more or less contaminated with soil, and their chemical composition places them almost on an equality with modern Peruvian guanos. Attempts to utilize them for the preparation of nitrate of potash, for gunpowder-making, have not been successful.

The climate of parts of the African continent also favours the preservation of guanos; but if the deposits are allowed to remain for any great length of time, they lose almost all their nitrogen. Thus, the now exhausted deposits from Ichabo and Saldanha Bay contained respectively but 6 per cent. and 1¼ per cent. of nitrogen; while the fresh accumulations yearly formed there, and collected immediately, yield as much as 12 per cent. and 9 per cent. of nitrogen respectively. The water present is also reduced: in the first case, from 27 per cent. to 17; and in the last, from 22 to 12. The thinness of the recent deposits, however, makes it difficult to collect the material in a condition free from foreign bodies, such as sand and stones.

Small parcels of nitrogenous guanos have been derived from many other spots; the quantity has, however, been insignificant, and the list may be concluded with two kinds from the islands of the Pacific Ocean. That known as "Baker's Island" contains nearly 35 per cent. of phosphoric acid; while "Jarvis Island" shows little over 20 per cent. of that element. In neither case, does the nitrogen exceed ½ per cent. These guanos have found a market in Germany, but are very little known in this country.

Artificial Manures.—The term "artificial" is applied to those manures which are never used save in a manufactured state. They may be conveniently divided into two classes, ammoniacal and phosphatic: the former represented by sulphate of ammonia; the latter, by the various kinds of superphosphates, nitrophosphates, bone-manures, turnip-manures, &c.

Sulphate of Ammonia.—In the distillation of coal for the production of illuminating-gas, the nitrogen is liberated as ammonia. This is retained in the water which is distilled over, and in the so-called "gas-liquor," from the scrubbers through which the gas is passed (see Ammonia, p. 246). The proportion of ammonia held in these liquids will naturally depend upon the character of the coal used. The ammonia thus recovered exists principally as carbonate, with smaller quantities of hydrosulphate, sulphate, hyposulphite, sulphocyanate, and chloride, of ammonium. This last salt in some cases represents 50 per cent. of the total amount of ammonia compounds procured in the water distilled with the gas, none but volatile salts being absorbed in the water descending through the scrubbers. Gas-liquor may be used directly as a liquid manure, provided it does not contain an appreciable amount of sulphocyanates (which are highly poisonous to vegetable growths), and that it be considerably diluted with water. It is far more common, however, to distil the ammonia from the liquor, and to collect it in sulphuric acid, as sulphate of ammonia. This salt is sold commercially on a guaranteed basis of about 24 per cent. of ammonia, or more than 93 per cent. of pure sulphate. When the proportion of nitrogen is very large, sulphocyanates may be suspected. Their presence may be detected by the formation of a blood-red colour on the addition of ferric chloride to an aqueous solution. If phosphates exist in the solution, the reaction can be observed only in the presence of hydrochloric acid.

The spent oxide of iron used for purifying gas also contains some ammonium salts, principally sulphate, with a little sulphocyanate. This may be washed out and utilized.

When the gas is purified by sawdust soddened with sulphuric acid, the purifier will contain, when dry, about 12 per cent. of nitrogen, which is equivalent to more than 50 per cent. of ammonium sulphate. It is not all present as sulphate, however, cyanides and sulphocyanates existing also; but it is said that the sulphocyanic acid evaporates by keeping the material in bulk for some time, and, being very volatile, it can certainly be easily expelled by hydrochloric or sulphuric acid in the presence of heat.

Commercial sulphate of ammonia is a white or pinkish-coloured crystalline mass. It may be readily applied in the form in which it is sold by the gas-companies, and other manufacturers of the article. It is also occasionally added to other fertilizers, in order to increase the percentage of nitrogen.

SUPERPHOSPHATES.—"Superphosphates," using the term in its widest sense, consist principally of phosphatic minerals treated with sulphuric acid, for the purpose of rendering the phosphates soluble in water, and therefore easily accessible to the plant. It is not by any means certain that the phosphates would not be rendered soluble in course of time, if applied to the soil without previous treatment with sulphuric acid; on the contrary, in some parts of Germany, are found deposits of mineral phosphates, which contain so much iron and lime in proportion to their phosphoric acid, that they cannot economically be used in making superphosphates, and these are applied to the land in a raw state. But the point aimed at is to supply material for the sustenance of the crop immediately to be grown, and it is small consolation to apply a dressing whose effect will not be seen for years. Therefore, except under such abnormal conditions as those stated, all mineral phosphates are dissolved in sulphuric acid, before application to the ground.

The many varieties of superphosphate are in accordance with the diversity of material used in their production. As all the mineral phosphates employed, and which form the bulk of this class of manure, undergo the same preparation, a description of the manufacture may be preceded by a notice of the most important species of this raw material.

Mineral Phosphates.—The value of a mineral phosphate may be adjudged in a great measure from its chemical composition. The first thing necessary is a large proportion of combined phosphoric acid, yielding, after manufacture, soluble tribasic phosphate of lime,—always the chief ingredient upon which the worth of a superphosphate is estimated. But it must not be taken for granted that the mineral containing the most phosphate of lime will yield the greatest proportion of soluble tribasic phosphate, for this is by no means certain. The presence of several other substances will greatly detract from the value of the sample. These are principally free oxide of iron, alumina, fluoride of calcium, silica, and carbonate of lime.

Free oxide of iron and alumina act detrimentally in two ways:—firstly, by absorbing and wasting a large amount of sulphuric acid; and secondly, because superphosphates made from minerals containing large proportions of these materials have a tendency to "go back" in standard, that is to say, that a portion of the soluble phosphate becomes, after a time, insoluble again. It may therefore happen that a mineral poor in phosphoric acid, and free from these compounds, will yield a manure of greater value than another mineral having more phosphoric acid, but contaminated with these deleterious ingredients. Iron existing as pyrites is not so mischievous, as it remains undissolved.

Fluoride of lime is objectionable chiefly as an absorbent and waster of sulphuric acid, while the gas evolved from it is highly unpleasant and unwholesome. The same may be said of chloride of lime. Their presence must also decrease the proportion of soluble phosphate.

Siliceous matters have no chemical effect upon the process either one way or another; but, by adding to the weight and bulk of material, they lower the proportion of soluble phosphate.

Carbonate of lime is objectionable, when in very large proportions, from causing a waste of acid, and reducing the proportion of soluble phosphate, as any other foreign body must do; but it possesses, on the other hand, a physical property which renders welcome its presence in moderate quantity, that is, that the carbonic acid liberated on its conversion to sulphate of lime remains in the mass for a time in a gaseous form, and thus produces in the finished manure a certain porosity or lightness, which is very desirable; and, at the same time, the sulphate of lime formed causes the manure to dry rapidly, which is one of the most important points to be attained in practice.

These remarks will be quite sufficient to indicate that, while taking the chemical analysis of a phosphate as a groundwork, it will be necessary to supplement this (supposing the analysis, of course, to warrant it) by actually trying the material with regard to the amount of acid it requires, and its physical and chemical conditions, when newly made, and after a lapse of time.

A more detailed description will now be given of the mineral phosphates principally employed in the manufacture, and of those waste products from other branches of industry which are now made to contribute towards the production of artificial manures.

Coprolites.—The name "coprolites" is given to a large class of mineral phosphates, existing as nodules and fossils, in strata of various geological ages, and scattered widely over the globe. They have been supposed to be fossil animal excreta, but it is at least doubtful whether that is the true origin of all coprolites.

The most valuable beds of the mineral in this country are in the Upper Greensand formation, lying chiefly in Cambridgeshire, and merging into Buckinghamshire. These are known as "Cambridge" coprolites, and formed at one time almost the only mineral phosphate employed in this country. They are of a greenish-grey tint, and are washed from a stratum not exceeding 1 ft. in depth. Hitherto, their standard of tribasic phosphate has been very constant; but deterioration is now often visible. They contain more carbonate of lime than the other coprolites, while the iron present is almost entirely as sulphide and silicate. The principal ingredients vary as follows:—Tribasic phosphate of lime, 54–60 per cent.; carbonate of lime, 11½–18¼; fluoride of lime, 1¾–4⅓; oxide of iron and alumina, 3¼–5¼; insoluble siliceous matter, 6–8¾.

Suffolk coprolites are another variety, raised in that and some adjoining counties, from beds adjacent to the London clay, in the Tertiary formation. That decomposed organic remains have at least been the origin of their phosphoric acid, can scarcely be questioned; but it is doubtful whether these coprolites are of the same character as the "Cambridge," and whether they have not rather been calcareous pebbles, metamorphosed by the action of phosphoric acid. They were the first coprolites used in this country, and monopolized the market till better varieties were discovered; but they are much inferior to Cambridge, in containing less phosphoric acid, and much more oxide of iron and alumina. Alone, they are not sufficiently good for making a superphosphate which shall yield at least 25 per cent. of soluble phosphate; but they may be used with richer phosphates, such as Cambridge coprolites, in the proportion of 3 parts of the former to 1 of the latter. They much resemble Cambridge coprolites in shape, but are very hard, with a smooth surface, and brownish-ferruginous tint. Their tribasic phosphate of lime averages about 52½–61¼ per cent.; carbonate of lime, 10–17½; fluoride of lime, 1½–4½; iron and alumina, 4¾–10½; and insoluble matters, 9¾–12¼.

At Potton, in Bedfordshire, coprolites are quarried from the Lower Greensand formation; on the whole, they are inferior in quality to the preceding. The larger nodules equal "Cambridge" in proportion of phosphoric acid, but contain more oxide of iron; the lesser nodules are of very poor quality. The colour is reddish. Their approximate composition is:—Tribasic phosphate of lime, 30–54⅓ per cent.; carbonate of lime, 5–8; fluoride of lime, 4; iron and alumina, 8–20; insoluble matters, 15–25. The nodule bed is intercalated in a deposit of coarse ferruginous sand, and is exceedingly variable in thickness. The sand extends to the north-east of Sandy Heath, by

Everton, Gamlingay, and Caxton, but the phosphatic bed has not been discovered in this direction. The extension of both the sandy and the phosphatic beds in a south-westerly direction is determined by the river Ivel. The beds reappear at Ampthill, where they are worked for the coprolites, and may also be traced in the neighbourhood of Woburn and Leighton.

Wicken coprolites are an inferior kind from Cambridgeshire, generally resembling the Suffolk variety, and composed approximately of:—Tribasic phosphate of lime, 36 per cent.; carbonate of lime, 10; fluoride of lime, 2; iron and alumina, 12; insoluble matters, 28. The phosphatic nodules are embedded in a sandy matrix, and are of two colours, light and dark: the former resemble those of Potton; the latter are characterized by a smooth exterior, and a smaller percentage of phosphate. The workings have been abandoned for some time.

Another Upper Greensand coprolite is raised in the neighbourhood of Boulogne, and sent over to this country, for use with higher class phosphates. It occurs in large grey nodules, with frequent organic débris, and is widely distributed along the north-eastern coast of France, from Havre to the Flemish border. Though poor in phosphoric acid, its impurities are principally non-deleterious, and therefore its phosphate is more easily available. Analyses by Voelcker of 5 samples of Boulogne coprolites gave respectively:—Tribasic phosphate of lime: 45·97, 46·43, 46·43, 45·19, 38·61 per cent.; carbonate of lime: 8·07, 11·93, 10·27, 8·95, 11·66; fluorine (3 samples): 2·08, 2·77, 4·96; oxide of iron: 2·89, 3·63, 3·54, 6·24, 3·52; alumina: 3·09, 3·66, 3·64, 5·39, 4·94; insoluble siliceous matters: 24·98, 23·56, 24·93, 26·16, 28·45. France possesses two other important deposits of coprolites, known as the Ardennes and the Bellegarde beds. The former are of greater importance than the Boulogne coprolites, and are largely and successfully used in French agriculture, as a simple finely-ground powder. The annual production of these beds was estimated at 25,000 tons in 1872, and has very materially increased since. The Bellegarde coprolites may possibly exercise some local influence, but the low proportion of phosphoric acid in the material will prevent its wider application.

Coprolites are also said to be abundant in Germany, and to occur sparsely in Canada. Russian coprolites are, perhaps, rather better known, but they are of very poor character, giving:—Tribasic phosphate of lime, 33–48 per cent.; carbonate of lime, 5½; fluoride of lime, 3½; iron and alumina, 6; insoluble matters, 30¼–43.

Apatite.—Apatite is a definite crystalline mineral, and is the purest phosphate met with in an inorganic state. There are two varieties, known as "fluor-apatite" and "chlor-apatite," according as the lime not existing as phosphate is combined with fluorine or chlorine. Sometimes both forms are present. These minerals are found in veins, in primitive formations and volcanic rocks, principally in Scandinavia and Canada, but also in Bavaria, Bohemia, Saxony, and Switzerland, as well as in New York and New Jersey, in America. As they contain from 75 to over 90 per cent. of tribasic calcium phosphate, they are a valuable source of phosphoric acid, but a well-conditioned superphosphate can hardly be made from them alone. They answer admirably, however, in conjunction with phosphates containing less phosphoric acid and more carbonate of lime. They are very hard, and of vitreous appearance, with a colour varying from yellowish to greenish-white.

The vein of chlor-apatite, which was discovered some years since on the southern coast of Norway, has been worked on a considerable scale by the Bamble Phosphate Co., and others. The expense of preparing the rock for market by hand-trimming is great. The present annual production barely reaches a few thousand tons; while the extent of the deposit was estimated at 75,000 tons. Sometimes the mineral yields as much as 90 per cent. of phosphoric acid in bulk, but generally it does not exceed about 75 per cent. It consists essentially of:—Tribasic phosphate of lime, 75–90¾ per cent.; chloride of lime, 1½–4¼; iron and alumina, 2–3; siliceous matters, 1½–11½. Some samples also contain about 1½ per cent. of fluoride of calcium.

The Canadian variety is imported to a greater extent than the foregoing. It is a fluor-apatite, sometimes containing also carbonate of lime, which is said never to be the case with the Scandinavian mineral. Analyses show:—Tribasic phosphate of lime, 65–91 per cent.; fluoride of lime, 7½; chloride of lime, ¾; siliceous matters, 1–10⅓. The deposits consist of pockets or bunches, of crystalline structure, embedded in granite, gneiss, and mica-slate. Their occurrence in widely separated pockets, the cost of excavation and hand-trimming from the accompanying rock, and the great expense of transportation, combine to limit their consumption. The production hitherto has not been much above 10,000 tons annually, even if it has always exceeded 5000 tons. New England and Great Britain absorb almost the whole quantity raised.

Phosphorite.—The mineral known as "phosphorite" is a fluor-apatite, contaminated with quartz, and differing from all other phosphates in being pyro-phosphorescent. It is found principally in Spain and Portugal, and especially in the Spanish province of Estramadura (whence its common name of "Estramadura phosphate"); also at Arnberg, in Bavaria. It is a hard, yellow-tinted, crystalline body, moderately free from iron and alumina, and often wanting altogether in carbonate of lime. It yields a high class superphosphate, from 30 to 33 per cent. of its phosphate being rendered soluble; but the lack of carbonate of lime makes it non-porous, and difficult to get into a powdery condition. It is imported largely from Spain. Samples from cargoes indicate the following variations in its composition:—Tribasic phosphate of lime, 53–86 per cent.; carbonate of lime, 0–10½; fluoride of lime, 1–3½; iron and alumina, 1¼–4; insoluble matters, 4–21. Logrosan and Caceres are the two principal localities where the mineral is found in Spain. At the former place, are several distinct veins of phosphorite. The rock is blasted out, and the large pieces are cleaned by hand and hammer, and then assorted into high and low grades. The pieces of trimmed rock average 3–4 in. in thickness. The shipment necessitates great trouble and expense. The mineral is transported in heavy waggons, drawn by mules or oxen, and carrying 2–2½ tons, to the railway at Villanueva de la Serena. The cost of transport and handling till the phosphate is put on board at Lisbon amounts to almost 40*s.* a ton, and the expenses reach 60*s.* by the time it is landed in England. A railway to Villanueva would greatly reduce the cost, and would permit the delivery of enormous quantities of the material, to the exclusion of Carolina and other low-grade phosphates. This phosphorite may be depended on as yielding 75–85 per cent. of bone phosphate of lime, it can be raised and laid down at the mine's mouth for 12*s.* a ton, and it exists in enormous quantity. The construction of a railway or tramway as indicated would probably enable it almost to monopolize the markets of Europe.

On the other hand, the Caceres mines are more important at present, and form the chief competitors with Carolina phosphate in the English market. From 1866 to October 1875, the principal company at Caceres had furnished about 125,000 tons, receiving 8–14*s.* a ton, according to quality, for the rock at the mines. The cost of transport to Lisbon amounts to about 32*s.* a ton. Analyses of the mineral show bone phosphate of lime averaging 60–65 per cent. The total recent production has been about 25,000 tons yearly. Most of it comes to England, France consuming only a few thousand tons, and Spain itself none at all.

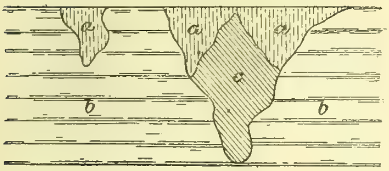
Phosphates.—Under the head of "phosphates," are included the remaining known phosphatic minerals, save a few non-nitrogenous guanos, which, however, resemble the Peruvian guano in little besides name. The best known phosphates are those occurring in pockets or patches in limestone formations in France (Bordeaux), Germany (Nassau), and Carolina; less important are the Russian and Bukowina varieties; while immense quantities are derived from the West Indian islands of Sombrero, Navassa, Maracaibo, St. Martin's, Curaçao, Oruba, and Pedro Keys. Besides the preceding, which are all phosphates of lime, there are two varieties of phosphate of alumina, known as Redonda and Alta Vela.

The French phosphate is raised in the departments of Lot and Tarn-et-Garonne, and is shipped to this country in large quantities from Bordeaux. It exists in fissures and cavities in the limestone, varying much in size and shape, whose whereabouts is generally indicated by outcropping threads of the mineral. It seems to be an aqueous deposit, and is sometimes found at but a short depth beneath the surface, in thin layers, underlying alluvial soils, which also contain a large proportion of phosphates, associated with iron and other impurities. This surface layer is unfit for manufacture, but is used on the spot in a raw condition. The appearance, quality, and texture of the mineral vary considerably. The richest specimens are hard, of white colour, and break with an earthy fracture. The bulk of it is harder and more compact, of a dark-yellow or brown tint, containing about 70 per cent. of phosphate; while some that is raised is of still poorer quality, dark-agate coloured, of waxy lustre, and seamed with veins of oxide of iron. This last has no important commercial value. The beds are principally in English hands. The best sorts, containing 70–80 per cent. of phosphate, and very free from oxide of iron and alumina, form superior manures; but as the phosphate decreases, the iron, &c., increase, so that the low grades are worthless for manufacturing purposes. The standard of the commercial article varies as follows:—Tribasic phosphate of lime, 50–80 per cent.; carbonate of lime, 8–15½; iron, alumina, fluorides, &c., 4–13; siliceous matters, 2½–19.

The phosphorites of the south occur in the three departments of Tarn-et-Garonne, Lot, and Aveyron. Fig. 932 shows a geological section of the bed as met with at Caylus (Tarn-et-Garonne): *a*, red clay; *b*, Jurassic limestone; *c*, phosphorites. These phosphorites are enclosed in cavities, resulting from the upheaval of the Jurassic formation, and are supposed to have been produced by the infiltration of phosphated water, and the subsequent evaporation of the water. The mode of occurrence of the phosphatic nodules of the *Tun* series, worked at Lezennes, in the department of Nord, is shown in Fig. 933: *a*, Tertiary sands; *b*, chalk; *c*, freestone; *d*, phosphates of the *Tun* series, in green chalk; *e*, chalk and flints. The phosphate beds at Mans, in Maine, occur as shown in Fig. 934: *a*, yellow sand in inclined beds; *b*, sand and sandstone blocks; *c*, foliaceous clay; *d*, sand and sandstone blocks, with nodules of phosphate; *e*, yellow sandstone. In the Ardennes, Orne, Eure-et-Loire, and Perche, phosphatic beds are found in the *Gaize*. A geological section of that of Céton (Orne) is shown in Fig. 935: *a*, siliceous clay; *b*, chalk containing pecten and asper fossils; *c*, *Gaize*, beds of nodules; *d*, astarte limestone. Nodular phosphates in the Gault are abundant in the departments of Ardennes, Pas-de-Calais, Meuse Aube, Haute-Marne, Yonne, Marne, Isère, Doubs, Haute-Saône, and Alpes-Maritimes. At

Wessant (Pas-de-Calais), they present a section as shown in Fig. 936: *a*, disturbed ground; *b*, small phosphatic bed; *c*, Gault limestone; *d*, bed of phosphatic nodules; *e*, green sand; *f*, green sandstone; *g*, pebbles; *h*, river. The phosphate of lime of the Lower Oolite occurs at St. Vigor (Calvados) as shown in Fig. 937: *a*, disturbed ground; *b*, white oolite; *c*, ferruginous oolite; *d*, beds of phosphatic nodules; *e*, bed of phosphate of lime; *f*, millstone grit; *g*, bed of flints; *h*, millstone grit. At Poillé (Sarthe), the nodular phosphates of the Lias present the section indicated in Fig. 938: *a*, Tertiary sands; *b*, siliceous clay; *c*, marl, and Upper Lias limestone; *d*, phosphate bed; *e*, marl, and Middle Lias limestone; *f*, Middle Lias conglomerate; *g*, Carboniferous limestone.

932.



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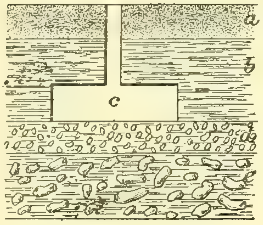

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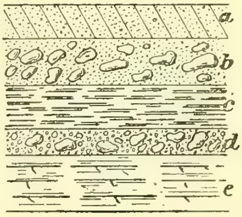

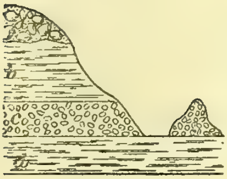

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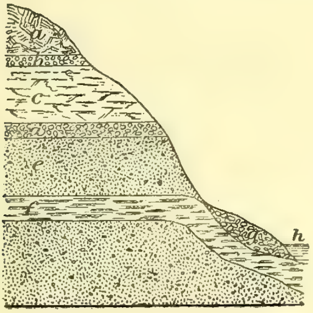

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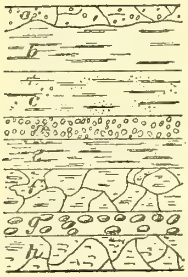

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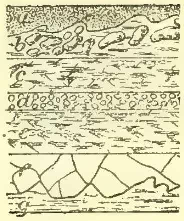


938.

No new deposits have lately been discovered in these regions, despite continued and careful prospecting; and an impression prevails that the better part, both in quality and quantity, has already been sent to market. The production has reached 20,000 tons a year.

The German or Nassau phosphate occurs in a manner very similar to the last-named, near the rivers Lahn and Dill, in the Rhine basin. It is also equally variable in composition and aspect; sometimes it breaks with an earthy fracture, and is of yellow hue; again it will occur as a phosphatic concrete, cemented by ferruginous matter; and the crystalline form is not unknown. The best sorts are fairly free from iron, and make a good dry superphosphate; but they set extremely hard. For a time, they were abundantly used here, but the supply is now trifling. The lower qualities, like those of the Bordeaux mineral, are useless for manure-making, and for identical reasons. They are similarly employed in a raw state on the spot. The better classes have a varying constitution, as:—Tribasic phosphate of lime, 58–71 per cent.; carbonate of lime, $4\frac{1}{2}$–8; iron and alumina, $4\frac{1}{4}$–15; insoluble matters, $2\frac{1}{2}$–12. It possesses a distinctive peculiarity in the presence of appreciable quantities of iodine, which is often driven off in violet vapours, on the addition of sulphuric acid.

South Carolina or Charlestown phosphate is very similar in composition to the best coprolites, but differs widely from them in appearance. It is found in the calcareous formation of the Charlestown basin, partly underlying the city, and occupying an area amounting altogether to perhaps 50–60 square miles. The deposits are distinguished as "land" and "river," each having its own peculiarities. The mineral occurs in rough nodules, perforated by boring molluscs, and associated with marine and terrestrial animal fossils, in thick strata of clay and sand, the cavities in the phosphate being mechanically filled with these substances, from which they can be cleansed by washing. The phosphate appears to be a converted Eocene marl, and is very uniform in composition. The river phosphate is of dark-grey colour, and is obtained by dredging in the Bull, Soosaw, and Stono river-beds. It is much the harder of the two varieties, and is difficult to grind; but is very superior for superphosphate-making. Though not containing so much phosphoric acid as the best Cambridge coprolites, it is distinctly preferable to them, on account of its much lower percentage of carbonate of lime consuming less acid; also by reason of the pyritous nature of nearly all the iron, and from its possessing physical characters which enable the acid to act on it with much better effect. It has replaced Cambridge coprolites to a great extent in this country. Its composition is represented as follows:—Tribasic phosphate of lime, 54–58 per cent.; carbonate of lime, 12¾–14; fluoride of lime, 1–2½; iron and alumina, 3½; insoluble matters, 13½–15. It is now often dried in hot-air flues before exportation, and is then called "calcined phosphate," yielding:—Tribasic phosphate of lime, 57½–59 per cent.; carbonate of lime, 11¾; siliceous matters, 12¾. The land phosphate is inferior to the other in most respects, and is consumed almost entirely in home markets. It has a yellowish colour, and is softer, and more easily ground; but more difficulty and expenditure are entailed in cleansing it than is needed with the river kind, which can be washed at the same moment that it is dredged up. For this reason also, combined with the presence of its iron as oxide, it yields a lower grade of soluble phosphate, and is consequently less valuable. The mean of eleven estimations gives:—Tribasic phosphate of lime, 53½ per cent.; carbonate of lime, 8¾; iron and alumina, 7¼; siliceous matters, 14.

Russia is said to possess some 12,000 square miles of phosphate-producing country, but analysis indicates nothing higher than 33 per cent. of tribasic phosphate. In the Bukowina, also, there are some deposits, declared to be rich on the average. The Russian phosphate occurs generally in the strata of the Cretaceous formation; it is also found in the Jurassic, Tertiary, and even Silurian. An examination into its commercial value led to the conclusion that, where the phosphate is accessible, its quality is too low to admit of more than local utilization; while the richer nodules, disseminated as they are throughout a compact formation, cannot be mined profitably. Only one attempt has been made at local agricultural utilization of these vast deposits: that ended in failure.

Of the large class of "rock-" or "crust-" guanos from the coral islands of the Caribbean Sea many are called "guanos," without any regard to their origin, which in some cases remains in obscurity. Seeing that they contain no trace of nitrogen, the term "phosphate" seems more appropriate.

The most important and valuable variety is named after the island of Sombrero, on which it is found. The islet, which is only about 2½ miles long, ¾ mile wide, and 20–30 ft. above the level of the sea, may almost be said to be composed of phosphatic materials; and the fragments of bones, found in the rock, have led to the supposition that the remains of turtles and other marine animals may have collected in the coral, while it was yet a shoal, and that bird-droppings assisted in cementing the mass together. The phosphate varies in colour, and is sometimes porous, at other times dense. It is at present worked below the waves, and probably the coral foundation on which it rests is now almost reached, as the mineral contains much more carbonate of lime, with less of iron and alumina, than formerly. Dissolved alone, it makes a very superior superphosphate, of light-yellow hue. It contains:—Tribasic phosphate of lime, 69–76 per cent.; carbonate of lime, 12–17; iron and alumina, 4–10; insoluble matters, 1–2.

Navassa phosphate exists in the form of pisolitic grains, of bright-red colour, cemented into hard masses, in the rock-cavities of the island whence it is named. It contains only a moderate amount of carbonate of lime, but its proportion of iron, and still more of alumina, is so great that it is impossible to make a superior superphosphate from it alone; moreover, the toughness and stickiness of the material during manufacture, and the hardness with which it ultimately sets, are additional drawbacks. Its large proportion of phosphate makes it useful for admixture with poorer materials. Its principal component parts are:—Tribasic phosphate of lime, 55–70 per cent.; carbonate of lime, 4–6; fluoride of lime, 0–2; iron and alumina, 23–28; insoluble matters, 3¼–5.

Maracaibo or Monk's Island produced a very superior phosphate, which was principally used in manufacturing the so-called "phospho-guano," but which is now exhausted, or nearly so.

St. Martin's Island, of the same group, now yields a valuable article, but which sometimes contains a large proportion of carbonate of lime. It varies thus:—Tribasic phosphate of lime, 52¾–76½ per cent.; carbonate of lime, 15–32¼; iron and alumina, 2¾–4½.

The island of Curaçao furnishes a valuable phosphate of lime, in an unmineralized and finely divided state, which may be applied in its natural state, or employed to manufacture very superior superphosphates, as much as 38 per cent. of soluble tribasic phosphates having been got out of a damaged sample showing only 65 per cent. of tribasic phosphate before treatment. The possibility of attaining such a high standard, even from a comparatively inferior sample, is due to the fact that none of the phosphate appears to be contaminated to any extent with iron and alumina, and that carbonate of lime and siliceous matters are almost equally conspicuous by their absence. The proportion of tribasic phosphate of lime rises as high as 80 per cent., and averages about 70.

Another of the Leeward Islands, called Oruba, yields a tolerably rich phosphate, but it is apt to be strongly contaminated with iron and alumina. It chief ingredients are:—Tribasic phosphate of lime, 63¼–76¼ per cent.; carbonate of lime, 2¼–15¼; iron and alumina, 14½–26½.

Redonda and Alta Vela Islands produce phosphates in which the lime has been entirely, or nearly so, replaced by alumina; these are, therefore, quite valueless for manuring purposes.

There remain but the phosphatic guanos to be mentioned. The best of these is procured from Mejillones, on the Bolivian coast, and is employed in manufacturing the compound known as "biphosphated guano." Besides about 71 per cent. of tribasic phosphate of lime, it has nearly 1 per cent. of nitrogen, with less than 2 per cent. each of carbonate of lime and siliceous matters, and scarcely any iron and alumina.

Browse Island guano is closely similar to Mejillones, but somewhat superior. It is imported in a fine powder, free from lumps and stones, and ready for treatment with sulphuric acid, without any grinding or other preparation. It contains about 1½ per cent. of ammonia, and yields a superphosphate up to 40 per cent. soluble; at the same time, it contains no fluorine, very little iron and alumina, and only a convenient proportion of carbonate of lime.

Malden Island guano, as well as that from Howland and Starbuck Islands, all of the same archipelago, have been principally used in Germany, for the preparation of high-class superphosphates. The first-named contains nearly ½ per cent. of nitrogen, besides tribasic phosphate of lime, about 73½ per cent.; carbonate of lime, 12½; ferric oxide, 1.

The following is a comparative statement of the percentages of phosphoric acid in the various natural phosphates and in the superphosphates made from them:—

Commercial Phosphates: Localities.	Percentage of Phosphoric Acid in the Natural Phosphates.	Percentage of Phosphoric Acid in the Superphosphates made from them.
Rio Grande—Bone-ash	39·84	13·98
Mejillones—Guano	33·23	18·58
Phœnix Islands—Rock-guano	39·08	17·18
Sombrero—Rock-guano	37·51	16·90
Curaçao—Rock-guano	32·52	15·80
Swan Island—Rock-guano	..	13·83
Navassa—Rock-guano	33·18	11·42
Elrogue—Rock-guano	32·00	Wet.
Redonda—Rock-guano	40·19	Wet.
Cambridgeshire—Coprolites	26·47	10·09
Cambridgeshire—Coprolites	25·95	10·02
Ardennes—Coprolites	20·71	7·60
Grandprè—Coprolites	17·13	5·34
Varennes—Coprolites	21·91	5·14
Bellegarde—Coprolites	23·37	8·36
Bordeaux—Phosphate	38·64	14·98
Bordeaux—Phosphate	21·46	5·04
German—Phosphate (best)	34·88	16·61
German—Phosphate (inferior)	17·56	8·08
Peine—Coprolites	14·38	5·82
Horde—Black band (phosphate)	19·48	1·46
Russia—Government of Orel (phosphate)	18·35	Wet.
Odegaarden—Apatite	37·66	15·41
Spain—Phosphorite (best)	38·05	14·04
Spain—Phosphorite (inferior)	20·15	9·20
Logrosan—Phosphorite (yellow)	37·55	16·20
Logrosan—Phosphorite (rosy)	42·17	18·10
Zarza la Mayor—Phosphorite	36·26	15·49
Caceres—Abundancia mine	27·00	13·62
Caceres—Estrella mine (white)	29·09	14·72
Caceres—Esmeralda (rosy)	37·38	15·94
Canada—Apatite	39·80	19·59
Carolina phosphates—		
Cooper River—Land deposit	..	10·70
Ashley River „ „	..	12·30
Ashley River „ „	..	9·68
Between Ashley and Rantowles—Land deposit	..	15·53
Between Ashley and Rantowles— „ „	..	11·17
Wando River—River deposit	..	10·30
Stono River „ „	..	12·54
Edisto River—Land deposit	..	11·79
Edisto River „ „	..	9·95
Edisto River „ „	..	10·43
Ashepoo River „ „	..	12·51
Ashepoo River „ „	..	14·55
Ashepoo River „ „	..	11·67
Bull River—River deposit	..	12·73
Soosaw River „ „	..	14·16
Beaufort River „ „	..	10·14

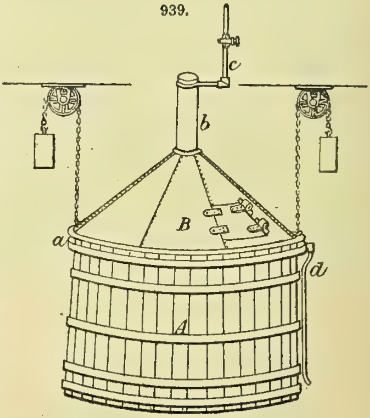
Bone-ash.—Bone-ash is another useful product, containing 60–80 per cent. of phosphates. It consists of calcined bones, contaminated with more or less of foreign substances. Their nitrogen is driven off by the calcining, and is generally wasted. Bone-ash is imported mostly from S. America, also from the Baltic and Black Sea ports. It is rarely or never applied in its imported state, but is generally ground in mills, such as are used for reducing mineral phosphates, described further on. In a finely comminuted state, it is employed in producing the better class superphosphates, or "bone-manures."

Shoddy.—Woollen refuse and hair, generally known in the market as "shoddy," are essentially nitrogenous manures. Pure dry wool or hair contains about 17 per cent. of nitrogen, but the commercial article commonly varies between 6 and 8 per cent. When applied in a crude form, it decomposes very slowly, and its benefit is observed for several seasons. Treatment with sulphuric acid hastens its absorption; and it is often employed in the manufacture of other manures, solely as a source of nitrogen.

Animal Charcoal.—This is a phosphatic material, consisting of the ash produced by burning bones in close vessels (see p. 453). It is used in sugar-refineries, and other works, for purifying purposes, and when no longer efficacious in this respect, it finds a market with manure-manufacturers. The amount of phosphates contained in it may vary from 50 to more than 80 per cent., according to the purpose for which it has been employed. Before being used as a manure, its phosphates are always rendered soluble by treatment with sulphuric acid; generally it forms only an ingredient of superphosphates.

Sugar-scum.—The term "sugar-scum" is applied to a compound obtained from sugar-refineries, containing not only the solid impurities of raw sugar, but also occasionally the coagulable constituents of blood used in the refining process, as well as bone-char, when the char-dust is utilized by mixing it with the solution of sugar in the "blow-up" pan (see Sugar). Analyses of a series of sugar-scums in actual use by manure-manufacturers reveal great variety of composition:—(1) Phosphate of lime, 11·75 per cent.; ammonia, 1·18. (2) Phosphates, 26·00; ammonia, 3·4. (3) Phosphate of lime, 6·16. (4) Phosphate of lime, 3·14; nitrogen, 1·22 = ammonia, 1·48 (equal, in dry scum, to nitrogen, 2·88 = ammonia, 3·49). (5) Phosphate of lime, 10·8; nitrogen, 0·98 = ammonia, 1·19. (6) Phosphoric acid, 7·14; nitrogen, 1·36 = ammonia, 1·65 (equal, in dry scum, to nitrogen, 1·83 = ammonia, 2·22). (7) An analysis of the dried contents of the filter-bags at a sugar-refinery where no blood is used gave:—Moisture, 3·5; organic matter, 41·6 (containing 17·8 sugar, and 0·5 nitrogen); ferric oxide, 0·72; alumina, none; phosphoric acid, 2·03; lime, 22·5; magnesia, 1·83; sulphuric acid, 6·82; chlorine, none; carbonic acid, 11·3; insoluble residue, 7·76; alkalies and loss, 1·94. Comparative analyses of samples taken respectively from (*a*) the filter-bags of a refinery where no blood is used, and from (*b*) those of another (belonging to the same firm) where several pails of blood are added to each charge of the "blow-up" pans, gave the following results:—Moisture, *a* 48·58, *b* 46·95; organic matters, *a* 20·82, *b* 29·55; mineral matters, *a* 30·60, *b* 23·50. The mineral matter contained—phosphoric acid, *a* 4·03, *b* 2·24; and the organic matter—nitrogen, *a* 0·48, *b* 0·89 = ammonia, *a* 0·59, *b* 1·09. Comparing these results with those of analyses (4), (6), and (7) above, the quantity of nitrogen appears very much lower. The inference to be drawn from this is that scum from refineries where neither blood nor char-dust is used would probably be of little value to the manure manufacturer. That procured from one sugar-works is said to contain 18–20 per cent. of phosphate of lime. The exhausted bone-black from sugar-refineries contains about 58 per cent. of triphosphate of lime and magnesia, and 8·8 of carbonate of lime.

939.

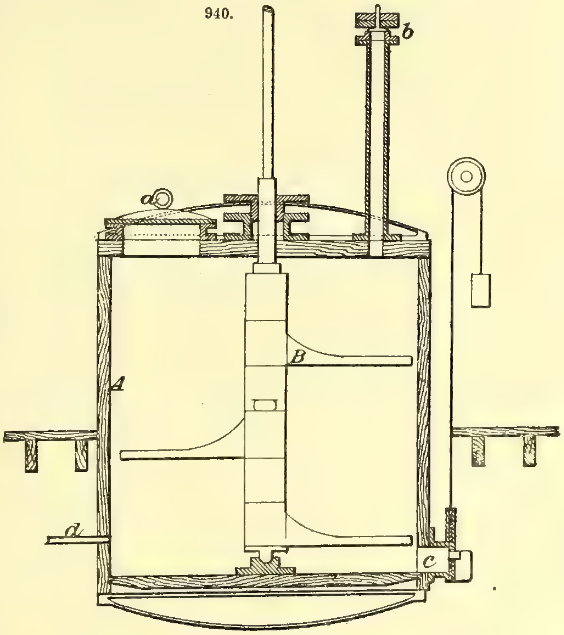


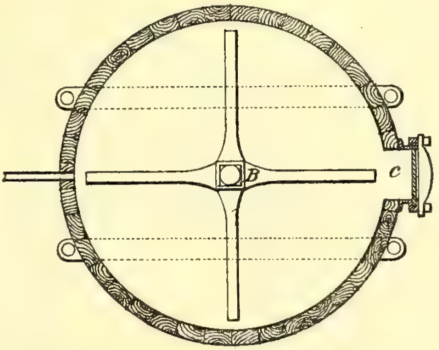
Scutch.—The term "scutch" is applied to the refuse from glue-works. It is usually treated with heat and sulphuric acid, to separate any fat it may contain, before being used for the manufacture of manure. Sometimes this is conducted in open or partially closed vessels by the aid of free steam; as the fat separates, it is skimmed off, and when all of it is removed, the residue is run off into a tray, to cool and consolidate. In some works, it is run into trenches dug in the earth, and after several months, is dug out, and dried in kilns or brick flues; at others, it is collected in a heap, and left to dry by spontaneous heating.

The chief point to be attended to is to deal with the scutch as early as possible after its removal from the glue-pan. An excellent apparatus for inoffensively extracting the fat from scutch is shown in Fig. 939. The scutch, mixed with acid, is heated by free steam in a large pan A, provided with a rim *a*, containing water, into which dips the edge of a conical cover B, so as to form a water-lute when the cover is let down. A short length of pipe *b*, closed at the top, rises from the apex of the cover, and is surrounded by a ring of perforated pipe *c*, from which cold water constantly flows over the outside of the cover, into the grooved rim of the pan, whence a waste-pipe *d* carries it away. By this means, the steam within is condensed, and runs down the inside of the cover into the rim. The fat is ladled out, and the residue is run off into a covered tank outside the works to cool.

Another form of apparatus is shown in Figs. 940, 941. The scutch and sulphuric acid are introduced into a close cylindrical leaden vessel A, encased in wood, and charged at the upper part through a circular opening *a*, about 18 in. wide, which is closed while working, by an iron cover screwed down. Within is a stirrer B, the shaft of which passes through the centre of the top of the vessel. When the cylinder has been charged and closed, steam at about 105° (220° F.) is admitted for 2 hours at *d*. Very little vapour escapes by the safety-valve *b*, and its odour is not perceptible outside the works. At the end of 2 hours, the steam is shut off, and the material is left to settle till next day. The fat is then ladled out through the charging-door, and the residue is run off through an opening *c*, about 14 in. wide by 5 in. deep, near the bottom of the vessel. Another method in use is as follows. The scutch, quite fresh from the pans, whence it is brought in closed vessels, is put into a tub with water and sulphuric acid; steam is injected to separate the fat, which is taken off, and the scutch is enclosed in coarse bags, and strongly pressed in a hydraulic press, to which steam is admitted. The fat flows off from the bottom of the press, and is collected and refined by remelting by steam-heat. The pressed scutch has no odour, and can be kept under shelter, without heating or becoming offensive.

940.





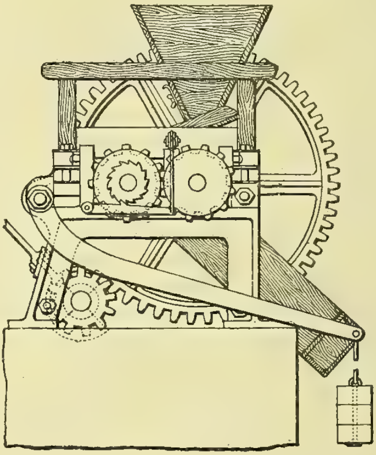
941.

Manufacture of Artificial Manures.—The next consideration is the means adopted for preparing raw materials for use as artificial fertilizers. It has been already remarked, that the greater part of the phosphate of lime existing in mineral phosphates is in a state that defies solution in ordinary water, and that, in order to render that phosphate soluble in water, and immediately available for the plant, it is dissolved by the action of sulphuric acid. The decomposition of the mineral would occupy such a great length of time, however, if the acid were to be applied to the unbroken nodules, that they are universally reduced to a fine state before being mixed with the acid.

Crushing.—The first process in the preparation of the mineral is that of reducing it to such a consistency as to admit of its being fed regularly into the mills which grind it to powder. This may be effected by the "crusher," shown in Fig. 942, consisting of a pair of chilled cast-iron rollers. Sometimes two pairs are arranged in the same machine, the lower ones being set somewhat closer than the upper. The mill may be fed with material about the size of road-metal. It is usually worked in conjunction with the grinding-stones, and is then driven from the same lay-shaft, to which the pinion and disengaging-clutch are attached, as shown. The method of driving may, however, be made suitable for any required position. Pressure is applied to the rollers by means of weighted levers, which may be varied according to the nature of the material under operation. These crushers are manufactured by E. R. and F. Turner, of Ipswich, in two sizes: the smaller, capable of crushing about 2 tons an hour, requires about 3 H.-P.; the larger needs double that power to reduce about 5 tons an hour. In some cases, so-called "edge-runner" mills are used, instead of the specially constructed crusher.

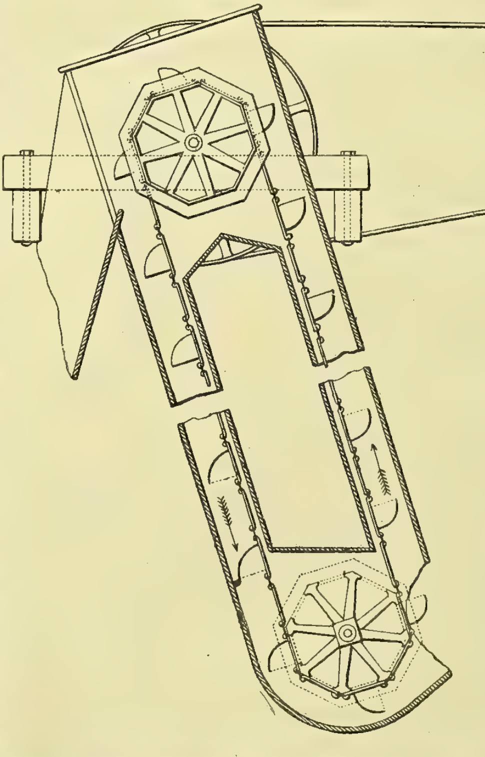
Grinding.—The material issuing from the crusher is taken by elevators, or by other suitable means, to be fed as required into the hoppers on the grinding-mill. These do not differ materially from an ordinary flour-mill. The bed-stones should be firmly secured in cast-iron coned pans, fitted with adjustment-screws; and the driving-wheels on the lay-shaft should be geared with hard and well-seasoned wooden cogs. These wheels may be made in halves, for facilitating the renewal of the cogs by means of a duplicate wheel. They work with iron pinions on the stone spindles.

942.

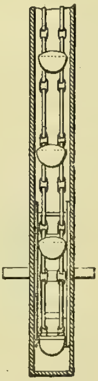


The stones are usually best French burrs, and are 4 ft. 6 in. in diameter. Each mill requires about 6 horse nominal engine power to reduce 10 cwt. an hour of the material from the crusher to a fine powder. It is very important that the phosphate shall be reduced to an exceedingly fine powder, especially when the mineral is very hard, as otherwise the acid will not have a fair opportunity of acting upon it, and consequently the proportion of soluble phosphate produced will be less than it might be. This fact has been demonstrated by experiments: of some samples of ground phosphates, fulfilling in all respects exactly similar conditions, it was found that the sample which had been ground to the finest powder gave 25¾ per cent. of soluble phosphates; while it was impossible to get far beyond 22½ per cent. with that which had been passed through a "38-wire" sieve. The material cannot, in fact, be rendered too fine; and a good plan is to regrind all that does not run through the hand as an impalpable dust, like flour, or the very best Portland cement. It should be caught from the mill in a sieve, and be constantly tested.

943.



944.



Mixing.—The dry materials to be employed in the composition of the manure, whether ground mineral phosphate, crushed bones, shoddy, scutch, &c., are raised to the "mixer" by some such apparatus as that shown in Fig. 943. This is a chain elevator, made by Turner, of Ipswich, and is found to answer exceedingly well. The charge of dry materials is shot down at the foot of the elevator, to be raised by the buckets, and deposited by them, in a constant and regular stream, into the hopper with which the top of the mixer is fitted. The elevator shown in the figure will deliver about 4–5 tons an hour; but they may be made with 9-in. buckets, to raise 8 tons in the same time. For ground materials alone, which yield readily to the buckets, ordinary pulleys with indiarubber belting may be used, instead of the octagonal pulleys and iron chain; but the latter repay their extra cost by longer wear.

Fig. 944 shows a front view of the buckets, with a portion of the casing removed. The requisite parts are two octagonal pulleys, cost about 2*l.*; double wrought-iron chain, about 1*s.* a foot; plate-iron buckets, with steel mouth-pieces, each 2*s.* 9*d.*; and bolts and nuts for ditto, about 1*s.* 3*d.* a doz. As the pitch of the chain is $8\frac{1}{4}$ in., and every alternate link carries a bucket, there will be one bucket required for every $16\frac{1}{2}$ in. of chain, and 2 bolts and nuts to each bucket. The elevator drum should travel at about 20 rev. a minute.

945.

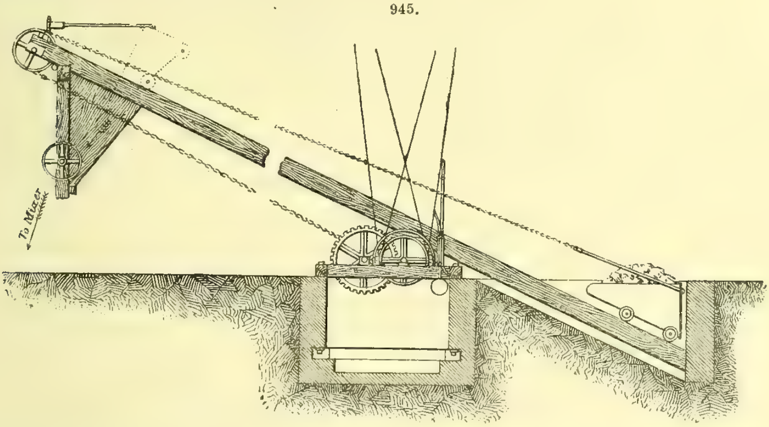
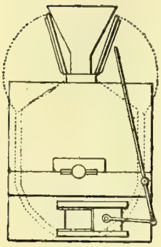
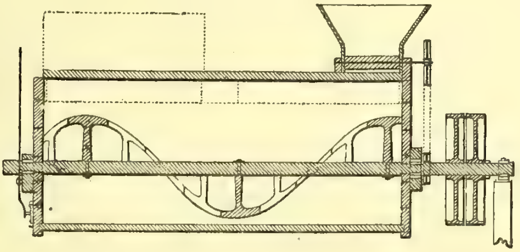


Fig. 945 shows another form of elevator for dry materials, which may be conveniently used when the latter have to be brought from a considerable distance; but as it is much more expensive than the preceding form, it is only adopted when circumstances compel it. The truck is filled with 4 cwt. of the ground material at the foot of the inclined plane, up which it is drawn by the chain. On reaching the top, the wheel is caught by a stop on the rail, and the contents of the truck are tipped into the hopper. The truck should make an ascent once in every three minutes.

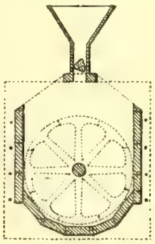
946.



947.



948.



The "mixer," shown in end view, and longitudinal and cross sections, in Figs. 946, 947, and 948, is also of Turner's construction. It consists of a stout wooden case of 3-in. deal, strengthened by longitudinal tie-rods of $\frac{5}{8} \times \frac{3}{4}$ in. round iron. The boards are all planed, and ploughed and tongued; the tongues are 1 in. × $\frac{1}{4}$ in., and are placed in the centre of the thickness of the boards. The top of the case consists principally of one board 9 in. wide, to which are hung four doors or covers, two on either side. The durability of the case is increased by lining it with "14-lb." lead, at an extra cost of about 20*l.* Iron cases have been tried, but have proved less durable than wood. Through the case, passes an octagonal shaft or spindle of cast-iron, into which cast-iron stirrers are wedged helically along its length. The price of such a machine, with feed-roll, hopper, and driving-pulleys, will be about 50*l.*; and its weight, say 35 cwt. The driving-strap should be 5 in. wide; and the speed, 80 rev. a minute. The power required is about 4 H.-P.

The action of the machine may be made continuous or intermittent. In the latter case, it is charged about once in every 3–5 minutes with 4–5 cwt. of ground materials, and the proper proportion of acid; it will then turn out about 8–10 tons of manure an hour. By the time that the compound reaches the exit of the mixer, it should have become very uniformly mixed. The smaller sized mixer will make about $1\frac{1}{2}$–2 tons an hour, and needs little more than 1 H.-P. It is of primary import that the acid used be of one constant degree of strength, or as near thereto as is practicable, and that the quantity used in each charge or mixing be accurately proportioned to the needs of the raw material. Chamber acid, which is ordinarily made at about 115° Tw., is perhaps the best suited for the purpose, as it is sufficiently strong, and is, at the same time, not so strong as to need the addition of water. When the manure-manufacturer also makes his own acid, it may be conveniently run from the chambers; but as it would be very difficult to regulate minutely the delivery of a certain quantity of acid from so large a vessel as the leaden chamber, it is preferable to let the acid run first into a lead-lined tank, holding about 10 cwt. of acid, placed near the mixer, and at a height of about 4 ft. from the floor. A floating gauge-glass will readily indicate the height of the acid; and at the side, may be fixed a leaden rule, graduated into divisions, each representing 10 lb. of acid. The tank communicates with the mixer by a 3-in. leaden pipe, fitted with an earthenware tap; by these means, and by observing the index, the attendant can regulate to a nicety the exact quantity of acid to a given weight of dry material. When the mixing is conducted intermittently, it is well to take care that, after a mixing has been let out, and the exit door has been closed, the flow of acid into the mixer shall be in advance of the dry materials, rather than allow the latter to precede the former, as, in this case, a hard, dry mass may accumulate at the mouth of the mixer, and create much trouble.

Figs. 949 and 950 show a complete arrangement of manure-making apparatus:—*a* is the mixer, which is supplied with dry stuff by the elevators *b*, and with sulphuric acid by the pipe *c* (having a plug at *d*) from the cistern *e*, which is filled from the chamber by the pipe *f*; *g* is the pit or "den," into which the manure is delivered by the mixer; and *h* is the platform for the man who regulates the supply of acid, and opens and closes the delivery-hole of the mixer, by means of the sliding door, worked by a lever, as shown in Fig. 946.

The following are practical notes on the quantity of concentrated sulphuric acid (say 168° Tw.) required by different kinds of phosphatic materials:—1 ton Cambridge coprolites, 60 per cent. phosphate, requires about 14½ cwt.; 1 ton Suffolk coprolites, 50 per cent. phosphate, 15 cwt.; 1 ton Spanish phosphorite, 68–70 per cent. phosphate, 14¾ cwt.; 1 ton Navassa phosphate, 73 per cent. phosphate, 14¾ cwt.; 1 ton of a mixture of two parts Cambridge coprolites, and 1 part bone, 14 cwt.; 1 ton of a mixture of 2 parts bone-ash (70 per cent.), and 1 part ½-in. bone and bone-dust, 13 cwt. When "chamber acid" is used instead of oil of vitriol, an increased quantity of acid, varying in inverse proportion to its strength, will be required. The following table shows the number of pounds of chamber acid, according to its density, required for 1 ton of Cambridge coprolites; opposite the quantities, are stated the corresponding depths of acid in inches and tenths, as measured from a cistern having the dimensions 6 ft. × 4 ft.:—

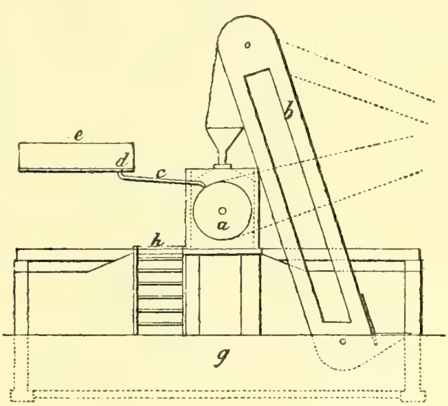
Strength of acid.	Quantity required.	Depth in Cistern.	Strength of Acid.	Quantity required.	Depth in Cistern.
° Tw.	lb.	inches.	° Tw.	lb.	inches.
100	2005	10·7	113	1922	9·8
101	1999	10·7	114	1916	9·75
102	1992	10·6	115	1911	9·7
103	1986	10·5	116	1904	9·65
104	1979	10·4	117	1898	9·6
105	1972	10·35	118	1892	9·55
106	1966	10·3	119	1886	9·5
107	1960	10·25	120	1880	9·45
108	1954	10·2	121	1874	9·4
109	1948	10·1	122	1868	9·3
110	1941	10·05	123	1863	9·25
111	1935	10·0	124	1857	9·2
112	1928	9·9	125	1851	9·1

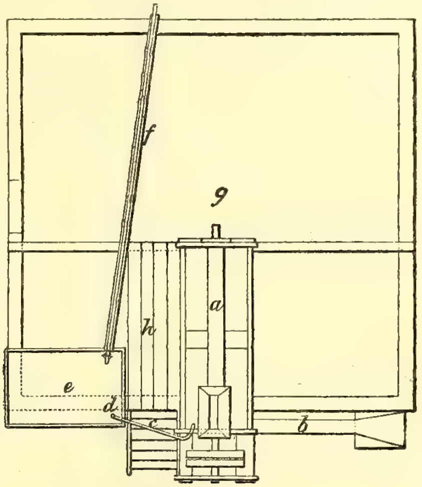
The effect of the chemical action of the acid on the phosphate is the generation of considerable heat, which is of great service in rendering the manufactured article thoroughly dry, so that it can be reduced to a moderately fine powder. For the purpose of conserving the heat, it is common to make the mixer-pit of very large size, capable of holding as much as 100 tons at one time; and it is found that much greater proportions of soluble phosphate, and altogether vastly superior manure, can be got by mixing these large quantities, than by treating little batches.

Mention has already been made of the ill effect exercised by ferric oxide and alumina, in causing the manure to "go back" in quality. Some experiments made were thought to show that the evil could be remedied by mixing such phosphates in small quantities, so that the heat of the mass should be far less considerable. But it was soon found that, besides producing a manure of very inferior physical qualities, the plan only had the effect of postponing the deterioration in chemical qualities, and did not in any degree prevent it. In working with phosphates whose "setting" power is good, depth is not essential in the den; but in all other cases, it is absolutely necessary, and better results are obtained in proportion as the shape of the den approaches more nearly that of a cube (omitting the corners). One manufacturer, of great experience in using German phosphorites, prefers a den of large area, so that the manure may run out thin, and cool quickly, and he thinks that this considerably lessens the liability of some manures to "go back." On the other hand, this idea is contradicted by the experiments just alluded to, and, in running the manure out very thin, there is always great risk of destroying the uniformity of the mass, particularly when bones form an ingredient of the manure.

In cases where difficulty is experienced in obtaining a manure that will dry well, a small proportion of gypsum may be conveniently added, as a drier, if the phosphates used are of such high quality as to bear that admixture, and at the same time to yield at least 25 per cent. of soluble tribasic phosphate of lime.

949.





950.

The production of so-called "turnip-manures" and "dissolved bones" is achieved by the addition to the dry materials, before mixing, of such nitrogenous or ammoniacal matters as have already been mentioned. When bones are used, they are generally introduced in fragments of the size known as "half-inch"; in this form, they are so slowly acted upon by the acid that they remain in specks throughout the mass, plainly visible to the eye of the suspecting farmer.

Screening.—After allowing the manure to heat for 24–36 hours, it is dug out, and put through a machine for reducing it to a pulverulent form. The best machine for this purpose is that known as Carr's disintegrator. The material in passing through the machine is subjected to percussion from the bars of the cages which compose the latter, and which revolve in alternate directions at a high rate of speed. A casing or hood is necessary to prevent the scattering of the material, from the centrifugal force it acquires whilst under operation. The power required to drive the machine varies from 8-H.P. upwards, according to its speed, the quantity delivered, and the nature of the material. It is scarcely necessary to add that only a thoroughly dry manure can be disintegrated in this machine, nor indeed in any other, except with the greatest trouble.

Finally, the manure is weighed into gunny bags, holding 2 cwt. each; the mouths of these are sewn up with coarse twine; and, in this condition, the manure is conveyed to the land where it is to be used. The bags are seldom fit for re-use, and are more commonly charged for in the price of the manure, remaining the farmer's property. The destruction of the bags by the action of the free sulphuric acid in the manure, and the consequent occasional waste of their contents, may be much reduced by passing the bags through a mixture composed of 15 per cent. chloride of barium, 10 per cent. chalk, 5 per cent. glue, 5 per cent. glycerine, and 65 per cent. water, squeezing them between wooden rollers, and drying them. For transport abroad, manures are generally packed in barrels.

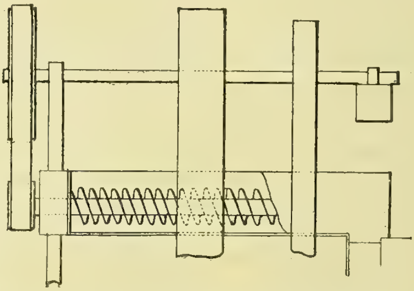
Poudrette.—The French word "poudrette" is applied to a preparation of sewage, or rather night-soil, with sulphuric acid. The acid is generally added to the excrement in the pails used to transport it to the works, and the whole is then tipped into a Milburn's desiccator, from which, when it has suffered sufficient evaporation, it is removed to a drying-floor heated by flues beneath. It is subsequently passed through a disintegrator, preparatory to being packed for sale. Sometimes a much more complicated system is pursued. The pails are first emptied upon a strainer, constructed to allow all liquid and fine suspended matter to flow through, while retaining the solid fæces, &c. The filtrate is pumped into an elevated tank, for the supply of a boiler capable of dealing with 550 gal. of liquid matter at a charge, and provided with a stirrer, to prevent incrustation. The boiler being charged, 80 lb. of dolomite (magnesian limestone) is added, and the whole is distilled by a fire below. The ammonia distilled off is conducted into an ordinary saturator, such as is used in making sulphate of ammonia (see Alkalies—Ammonia), containing brown sulphuric acid. The fœtid vapours evolved in the saturator are carried through a worm-pipe in the supply tank, partly for condensation, and partly to warm the contents of the tank before running them into the boiler. The condensed vapour is run off into the drains. The sulphate of ammonia thus made is evaporated in a shallow, open, leaden vessel, on the top of the saturator, and as it crystallizes, is drawn out and set to drain. Only $\frac{5}{8}$ of the ammonia is boiled off. The residue in the boiler, when this proportion has been collected, is run off by a valve at the bottom, and is stirred up with superphosphate in large wooden vats. The product is then dried, either by ordinary means or by pressure. The solid matters originally separated by the straining are mixed in a mortar-mill with the superphosphate and soot or waste charcoal.

To prevent nuisance arising from this manufacture, the whole process must be conducted within a closed building. The interior of the desiccator should communicate with a blower, creating an in-draught, sufficient to prevent the escape of effluvia through the crevices of the cover, or while charging the machine. Flues must be provided, so that the blower shall drive the vapours through the fires used for heating the drying-floor, before they escape into the chimney of the works.

Prevention of Nuisance.—In the process of manufacturing artificial manures, such as superphosphate, nitrophosphate, bone-manure, &c., very offensive and injurious vapours are abundantly evolved; consequently, a knowledge of how to prevent these vapours from becoming a nuisance to the neighbourhood is of vital importance to those engaged in the industry, particularly in a densely-populated country like England. Only a few of the largest firms have hitherto given much attention to the subject; but future legislation on the noxious vapours question will probably enforce upon all the precautions willingly adopted by a few.

The objectionable odours are generated chiefly in the apartments where the manure is mixed, and where it is received after mixing to set and cool—in other words, in the "mixer" and the "den." It is therefore essential that these should be made practically airtight, so that the gases may be kept under control. The first point is to prevent the vapours generated within the mixer from escaping through the hopper by which the solid materials are fed into the mixer. This is most efficiently accomplished by substituting the arrangement shown in Fig. 951 for the ordinary feed-hopper. It consists of a horizontal wooden box, kept completely and constantly full of materials, which are carried into the mixer by means of the archimedean screw working within the box. It can only be used when the mixing is continuous.

951.

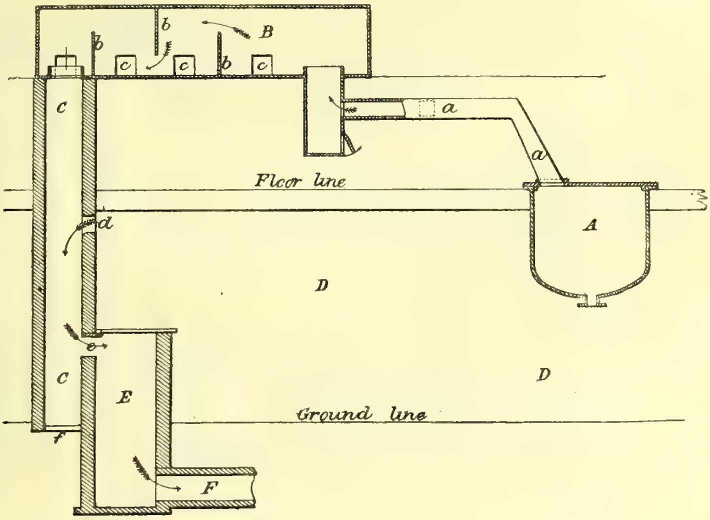


The manure, on flowing from the mixer, falls into the den, which is a close chamber, constructed of brickwork walls (best lined with cement plaster), and with a paved floor. In the walls of the den, are suitable wide openings for removing the manure when set; these are firmly closed by stout wooden doors during the mixing. The den is also securely roofed over, either permanently or temporarily, in such a way as to include the outlet from the mixer. When the manure is to be dug out of the den, the latter is ventilated by removing the roof, if temporary, or by opening windows provided for that purpose, if it be a permanent covering. As the vapours generated during the mixing of the manure, and immediately after its outlet from the mixer, are those chiefly to be dealt with, attention is mostly confined to means of drawing them away and rendering them innocuous.

No very complete analysis has yet been made of the constituents of the gases evolved in the manufacture of artificial manures. In the case of ordinary superphosphate, fluoride of silicon is formed by the action of the sulphuric acid upon the silica and fluoride of calcium contained in the said phosphates. The fluoride of silicon, in the presence of condensing watery vapour, is resolved at once into hydrated silica and hydrofluosilicic acid, thus—$3SiF_4 + 4H_2O = SiO_2, 2H_2O + 2(2HF, SiF_4)$. Dr. Adams has also conclusively proved the vapours to contain arsenic, from the arsenical sulphuric acid used, most of the acid employed for manure-making being derived from pyrites. Without doubt, some of the arsenic is evolved as arseniuretted hydrogen, from the action of the acid upon the iron portions of the interior of the mixer; but the greater part is probably in the form of chloride of arsenic. The proportion of the latter will be commensurate with the amount of chlorides decomposed in the mixing, and, estimated as arsenious acid, varies from 2 to 10 oz., and even more, for each ton of manure made. When organic matters are added to the raw constituents of the manure, additional offensive vapours are generated, of very various characters. When much salt is present, the production of hydrochloric acid vapour will be great. The odours from manure-works are carried considerable distances, extending sometimes to over 4 miles.

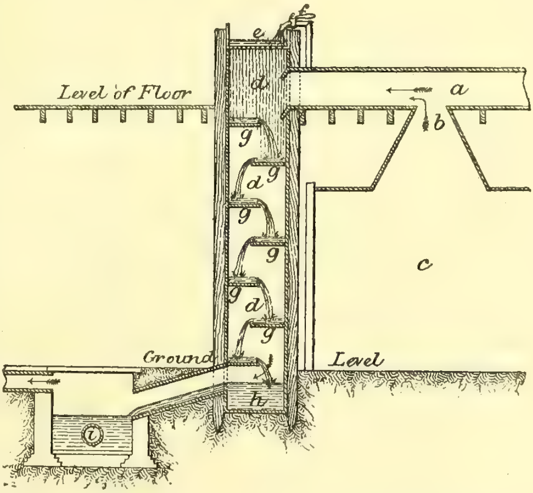
Of the offensive vapours given off during mixing, some are condensed by cold, some dissolve in (or are decomposed by) water, and the remainder are destructible by fire. The application of these agents — cold, water, and fire — resolves itself into long flues, water-towers or "scrubbers," and furnaces, usually assisted by motive power, such as that produced by the draught of a tall chimney, or by a fan.

952.



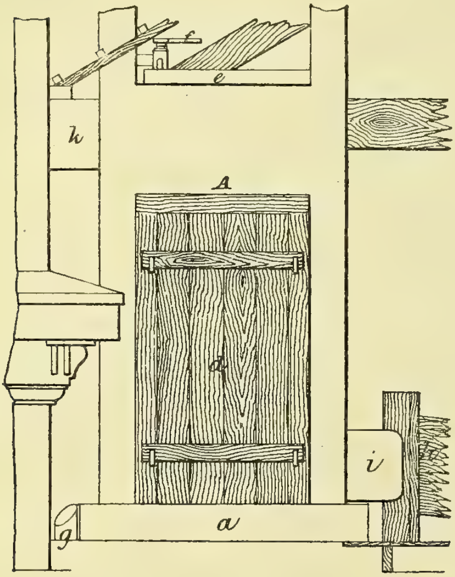
In simple superphosphate-making, a long flue seems to answer every purpose, and has been successfully adopted in some of the largest works. Its object is, by cooling, to promote condensation of the steam, and consequent deposition of the hydrofluosilicic acid, and other matters, before arrival at the chimney, by which they would otherwise escape into the atmosphere. In these flue deposits, is found a notable quantity of arsenic. An illustration of a thoroughly efficient arrangement is given in elevation in Fig. 952. The mixer A is connected by a short flue *a*, 12 in. square, with a wooden chamber B, about 18 ft. long, and 3½–4 ft. wide and deep, divided at equal intervals by partitions *b*, springing alternately from top and bottom. At the bottom of each partition thus formed, is a door *c*, by which the deposit is periodically removed. The chamber B opens into the top of a square brick tower C, about 14 ft. 6 in. high, and 2 ft. 7 in. in diameter, receiving at *d* the vapours arising from the pit or den D. In the tower C, more silica is deposited. Adjoining C at the bottom, is a shorter tower E, with a communication between the two at *e*, about 4 ft. above the bottom of the former. The deposit accumulated in C is thus prevented from choking the passage, and is removed by a door at *f*. From E, the vapours traverse an underground flue F, 150 ft. long, terminating in a chimney. The chief deposition takes place in B and C, the former being cleaned out twice a week, and the latter once a month. Beyond the first 15 yd. of the flue, the deposit is scarcely appreciable, and the flue is only cleaned out once a year. At the works where this plan is in operation, the manure made averages 100 tons a week, about half the raw phosphate being bones. At another works, making 300 tons a week, and employing nearly all mineral phosphates, the total flue is 440 ft. long.

953.



A second method, adopted successfully in some works, is to condense the vapours by the direct application of cold water. This is effected either by a shower or cascade, or by means of a "scrubber," i. e. a tower partly filled with material over which liquid is made to fall. A most efficient example of the shower or cascade arrangement is shown in Fig. 953. From one end of the mixer, an opening, the entire width of the mixer, and about 15 in. deep, communicates with a wooden channel *a*, into which emerges a similar connection *b* from the den *c*. At about 3 yd. from the mixer, the channel *a* communicates with the upper part of a water-tower *d*, where the vapours

954.



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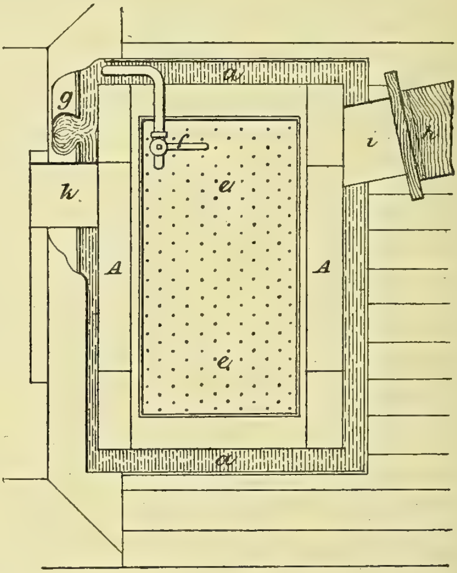
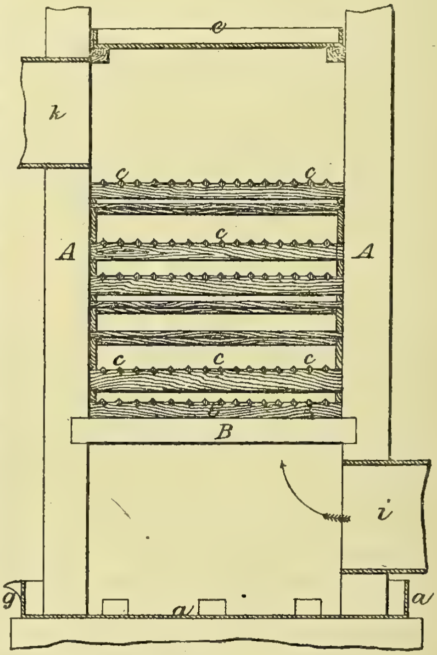


meet with a shower. The tower is of wood, 3 ft. square, and 18 ft. high. At the top, is a tank *e*, with a perforated zinc bottom, fed by a 3-in. tap *f*. Within the tower, a series of wooden shelves *g* spring alternately from opposite sides, with flanges to determine the flow of water towards their centres. At the bottom of the tower, is a cistern *h*, whence the water flows over a ridge into the drain *i*. The unabsorbed vapour is drawn off by a fan, and conducted into the boiler-fires of the works. With an abundant water-supply, nothing is more effective than this plan.

956.



The "scrubber" system is, however, in more general use. Its arrangement is shown in elevation, plan, and vertical section, in Figs. 954, 955, and 956. Leading from the mixers and the dens, are square wooden flues, terminating in a fan, which draws the vapours from the mixers and dens, and forces them into the condenser. This latter consists of a brick chamber A, standing in a strong leaden tray *a*. A range of lead-covered iron bars B is built into the brickwork, and supports the two first racks *b*, which are notched to receive the loose square wooden bars *c*. The racks are so disposed that the alternate sets of bars *c* are at right angles to each other. Upon each row of bars, are laid packing-pieces, to carry the next set of racks, and this is repeated to the top. The whole of these racks may be removed for cleaning, and replaced through the door *d*. At the top of the tower, is a perforated leaden tray *e*, supplied with water by a tap *f*. The water falls in a shower upon the intercepting bars within the condenser, and passes between them to the bottom of the condenser, whence it overflows at *g* into a drain. The vapours from the mixers and dens enter the condenser near the bottom, and beneath the bars B, by means of the wooden flue and pipe *h i*; and, after passing the condenser, escape near the top, by a short flue *k*, leading to the chimney of the works. The efficiency of this arrangement seems to depend less upon the flow of water, than upon the obstruction offered to the passage of the vapours, affording time for the decomposition of the fluoride, and the arrest of the products of the decomposition; but the water undoubtedly renders valuable assistance. The escaping vapours show no trace of fluorine compounds; but still contain an appreciable quantity of arsenic.

A still more effective form of scrubber is shown in Fig. 957. The condenser consists of three vertical chambers of brickwork A B C; the first contains nothing, but the second and third are packed in their lower portion with perforated bricks *a*, laid evenly, but not too closely. Above the three chambers, is a capacious cistern D, for supplying water to the condenser. From this cistern, the water flows by pipes *b* into each of the three chambers. There is an excellent arrangement for distributing the water, which is shown in detail in Fig. 958. The bottom of the pipe *b* is open, but capable of being closed partially or completely by means of a plate or button *c*, which can be raised and lowered by a screw-rod *d*, worked from above, and guided into a central position at *e*. When the plate *c* is slightly lowered, the water, entering the pipe *b* from the tank D by the perforations at *f*, flows out in a thin sheet resembling an open umbrella, and falls down through the chambers, being determined by the shelves *g* towards the centre of the chambers; then, passing through and between the perforated bricks *a*, escapes by the drain-pipes *h*. The vapours from the mixers and dens enter the upper part of the first chamber A by means of a 12-in. pipe *i*, then pass below, as shown by the arrow, into the second chamber B, and, after passing through the bricks, enter the third chamber C, above the sheet of water, with and among the spray from which they descend through the bricks, and escape by the flue, some 50 ft. long, which conducts them to the furnaces shown in Fig. 959.

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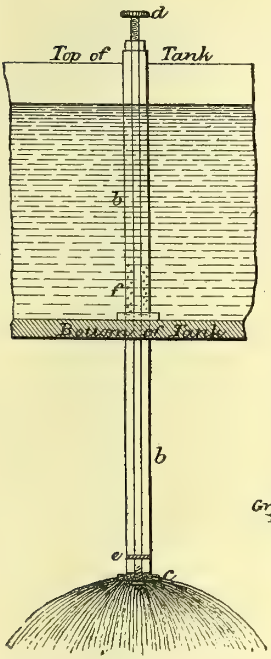

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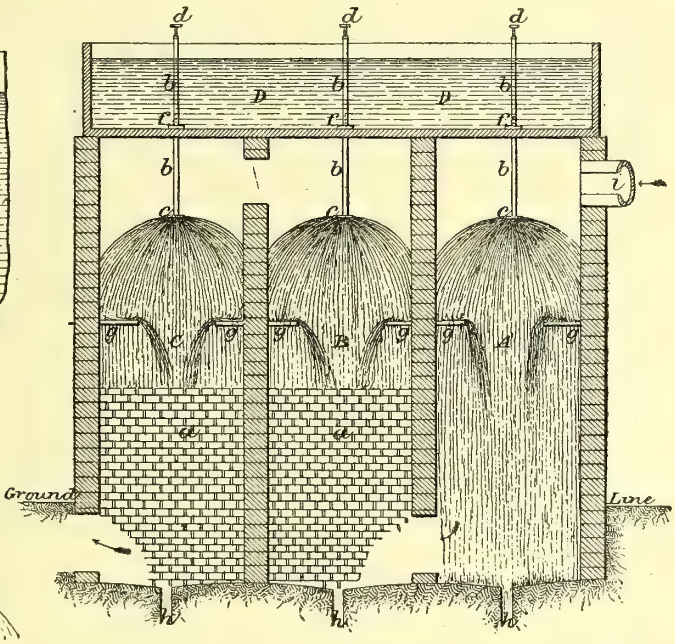
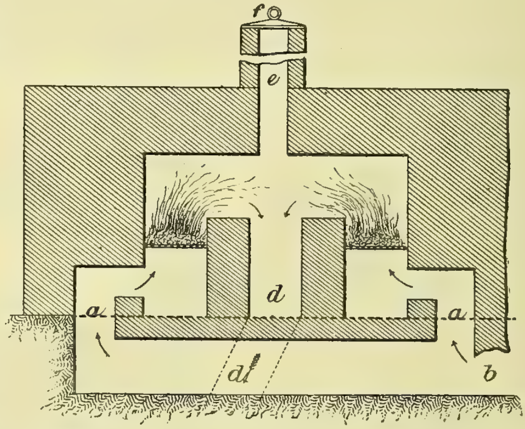


These furnaces are in duplicate, and provided with dampers at *a*, so that the vapours may be directed into either at will, on their entering from the condenser by the flue *b*. After passing through the fires *c*, the vapours descend by the flue *d*, and pass away to the chimney of the works. As a means of testing to what extent the vapours are deodorized, a small chimney *e* is provided; by closing the damper placed at the floor-line in the flue *d*, and removing the luted cap *f*, the vapours may be smelt. This combined arrangement of condenser and fire is perfectly efficient, and when kept in working order, the escaping vapours give no trace of arsenic, or other deleterious substance.

The result of these observations is to show that, in the case of manure made from ordinary mineral phosphates, the prevention of nuisance is efficiently ensured by affording the time, space, and other conditions necessary for the decomposition of the vapours, and the deposition of the condensed products; but that where animal and vegetable substances are used in the manure, not only must these precautions be rigidly observed, but complete success can only be obtained by passing the vapours through fire, to destroy their organic constituents. By the adoption of these combined measures, the operation of making the manure may be rendered absolutely innocuous and inodorous.

There remains to deal with the odours which arise during the subsequent operations of digging-out and screening the manure. It has been suggested that, by leaving the manure for a much longer time in the den, so that the imprisoned gases might have an opportunity to condense, all smell would be avoided; but this is a condition which would be practically impossible in many works, and onerous in all. The only practical solution of the difficulty seems to be by enclosing the den, and the apartment where the screening takes place, and to draw off all the vapours set free in these apartments, by means of a fan, passing them through a condenser and a furnace, as already described.

959.



General Considerations.—The importance of artificial manures in modern agriculture cannot be overrated, by far the greatest proportion of the vegetable products of all civilized countries at least being grown by their aid. It would be difficult to assign any distinct locality where this branch of chemical manufacture is carried on. The universal distribution of the agricultural industry furnishes sufficient reason for this. Perhaps it is most largely conducted in the immediate neighbourhoods where the raw materials are mined or quarried, and it is safe to assume that every sulphuric acid manufacturer is more or less engaged in making artificial manures; at the same time, there are a great number of smaller capitalists, who buy the raw materials, both mineral and acid, and supply local needs. The manufacture is a creation of the last 25 years, and is always spreading; it will no doubt continue to grow until some better means is found for economizing that great natural fertiliser—Sewage. The sum of money invested in the manufacture must amount to several millions. When the manure-manufacturer does not make his own sulphuric acid, the capital required is very small, as compared with other manufactures. Moreover it may be conducted on any scale, large or small. Legislation concerning the conduct of the manufacture is in a transition state; but probably next session will find manure-factories under the Noxious Vapours Act, which is not likely, however, to impose any restriction upon the trade, save the prevention of nuisance, which may be easily accomplished. The commercial prices of the manufactured articles vary so much that it is not easy to fix upon a general figure. They are usually sold on a basis of containing a certain proportion of the actively fertilizing principles—the soluble phosphate of lime, the insoluble phosphate of lime, the potash, and the nitrogen (as ammonia), being the elements which enter into the estimation. The values set upon these ingredients are approximately as follows:—Soluble phosphate in bone manures, 4*s.* 6*d.* per unit per cent.; soluble phosphate in mineral superphosphates, 4*s.*; precipitated phosphate, 3*s.* 6*d.*; insoluble phosphate, as bone, or from guano, 2*s.* 6*d.*; insoluble mineral phosphate, up to 7 per cent., 1*s.*; potash sulphate, 3*s.* 6*d.*; ammonia, 20*s.*; insoluble phosphate in good "dissolved bones" (when precipitated phosphate is not reckoned), 2*s.* 9*d.* This scale is adopted by Alfred Sibson, F.C.S., of 23, St. Mary-Axe, who is well known as an analyst of manures and feeding-stuffs. As between manufacturer and consumer, it is probably the most equitable of any. It assumes that the manures are sold under the conditions usually prevailing in agricultural districts, the article being in dry, powdery condition, supplied in bags, and carriage paid, and credit being given. The two prices for bone phosphate and mineral phosphate are not generally recognized by analysts; but the justice of the plan is evident, from the greater cost to the manufacturer of phosphate in the form of bones, and the greater expense in their manipulation. Many chemists, also, do not estimate the "precipitated" phosphate, or soluble phosphate which, by long keeping, has reverted to an insoluble condition, an occurrence frequently experienced, especially with bone-manures; yet the unfairness of not admitting the distinction is manifest. The greatest proportion of the artificial manures sold in this country pass first through the hands of commission agents, before reaching the actual consumers, the farmers.

Imports and Exports.—Our imports of bones of animals and fish for manurial purposes, in 1879, were:—From the Argentine Republic, 26,929 tons, 149,541*l.*; British E. Indies, 6678 tons, 38,567*l.*; Turkey, 5828 tons, 32,845*l.*; Russia, 5123 tons, 31,315*l.*; Brazil, 3989 tons, 23,156*l.*; Uruguay, 3394 tons, 18,794*l.*; Italy, 1981 tons, 11,691*l.*; Chili, 1877 tons, 10,458*l.*; other countries, 8439 tons, 49,405*l.*; total, 64,238 tons, 365,772*l.*

Our imports of guano in the same year were:—From Peru, 44,325 tons, 480,927*l.*; Islands in the Pacific other than Fiji, 10,938 tons, 48,832*l.*; Bolivia, 7232 tons, 44,937*l.*; Australia, 4054 tons, 18,644*l.*; W. coast of Africa, not particularly designated, 3517 tons, 45,421*l.*; China, 1472 tons, 15,500*l.*; Patagonia, 1412 tons, 7498*l.*; Chili, 1150 tons, 13,800*l.*; Uruguay, 596 tons, 4682*l.*; other countries, 2859 tons, 24,207*l.*; total, 77,015 tons, 704,448*l.*

Our imports of unenumerated manures in the same year were:—From the United States, 109,378 tons, 293,302*l.*; Germany, 38,659 tons, 112,213*l.*; France, 18,411 tons, 34,421*l.*; Portugal, 10,593 tons, 37,219*l.*; Dutch W. Indies, 9144 tons, 52,501*l.*; British N. America, 8129 tons, 29,917*l.*; Belgium, 6726 tons, 15,927*l.*; British W. Indies, 5478 tons, 26,714*l.*; Hayti and St. Domingo, 2190 tons, 6747*l.*; other countries, 6636 tons, 32,496*l.*; total, 215,344 tons, 641,457*l.*

The values of our exports of unenumerated manures in 1879 were:—To Germany, 542,860*l.*; France, 121,300*l.*; British Guiana, 79,530*l.*; foreign W. Indies, 54,928*l.*; Russia, 48,370*l.*; Sweden and Norway, 45,330*l.*; Denmark, 22,860*l.*; Belgium, 20,865*l.*; Channel Islands, 19,693*l.*; Holland, 18,850*l.*; British W. Indies, 15,370*l.*; Spain and Canaries, 12,188*l.*; Mauritius, 10,200*l.*; other countries, 25,716*l.*; total, 1,024,832*l.*

Bibliography.—J. C. Nesbit, 'Natural Guanos' (London: 1860); C. Morfit, 'Chemical Conversion of Guanos, Coprolites, and Phosphates' (London: 1873); J. J. Harris Teall, 'The Potton and Wicken Phosphatic Deposits,' Sedgwick prize-essay for 1873 (Cambridge: 1875); J. Adams, 'Arsenic in Vapours of Bone-Manure' (Edinburgh: 1876); J. Harris, 'Talks on Manures' (New York: 1878); A. Sibson, 'Artificial Manures' (London: 1878); A. Villanueva, 'Salitres i Guanos del Desierto de Atacama' (Santiago: 1878); W. Crookes, Ville's 'Artificial Manures' (London: 1879); R. H. Twigg, 'Sombrero Islands, and Submarine Quarrying of Phosphate of Lime,' Soc. Civil and Mech. Eng. (London: 1881); S. Pick, 'Künstlichen Düngemittel' (Vienna and Leipzig).

(See Acids—Sulphuric; Assaying; Bones; Cements—Glue; Leather.)

MATCHES (Fr., *Allumettes*; Ger., *Zündholzchen*).

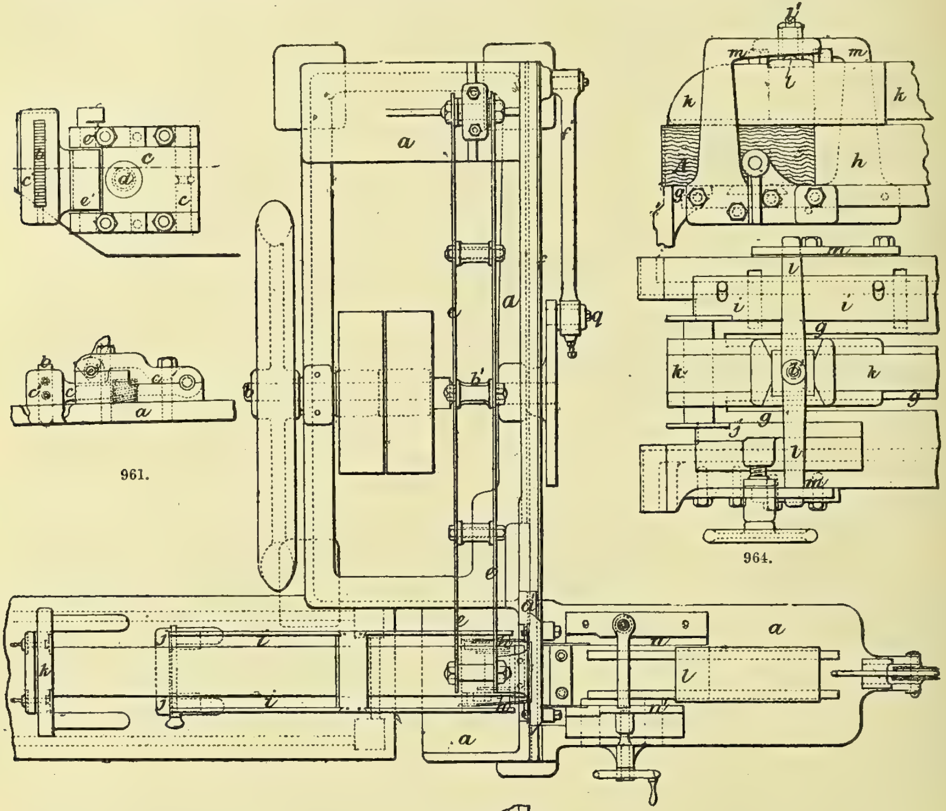
The manufacture of matches for lighting purposes is principally divided into three great branches, comprising the ordinary wooden match or "lucifer"; "vesuvians," which are principally used in the open air by smokers; and "vestas," in which a thin wax taper is substituted for the wood.

Splints and Splint-cutting.—The timber for match-making comes chiefly from Sweden and Canada, and is usually very straight-grained pine or aspen; it is sawn into 12-ft. lengths, 3 in. thick by 11 in. wide, and subdivided into blocks 5 in. long, representing two matches. If the timber is worked up in the neighbourhood of its growth, it can be cut into splints in the green state; but if it has been dried, it must be afterwards steamed for about 20 minutes. It is then passed through the splint-cutting machine, which cuts the whole into splints of the required size, only the last flake of the wood being wasted.

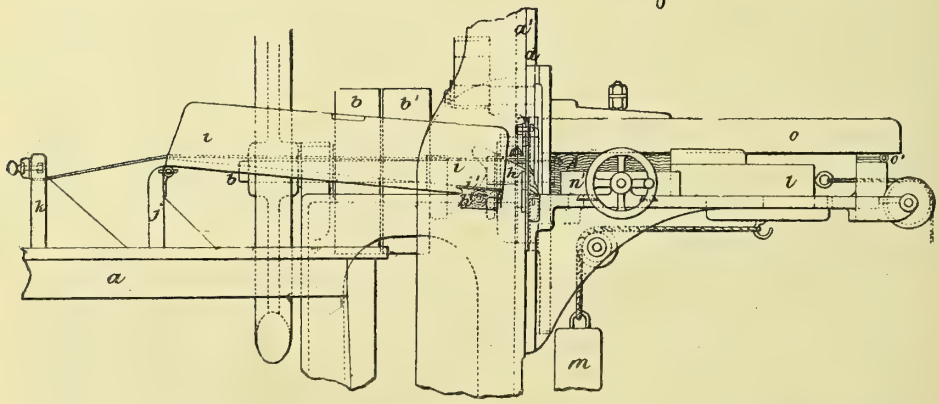
In the old method, the 5-in. blocks were cut by a vertical cutter into flakes having the exact thickness of a match; a number of these were placed together, turned at right angles to the former cut, and divided into splints. From time to time, machines have been introduced to cut the splints at one operation. One of the earliest (1859) was that of F. Tillett, in which a set of reciprocating lances grooved the block to be cut into splints, whilst a knife arranged at right angles sliced off the grooved portions. An improved machine of this type is used in Canada, and has been introduced in England by Pace and Howard. It is shown in Figs. 960 965: a is the framing of the machine; b, the driving-shaft, driven by a belt passing around pulleys on it. Fixed to b, are a crank b' and a crank-disc; c is the slicing-knife, fixed to the slide d, which works up and down in vertical guides, and receives its motion from the crank b'. On a standard a', is jointed one end of a lever e, the opposite end being connected by a link to d. The centre of e is attached to one end of a link p, the other being operated by the crank b', thereby giving the required motions to the slicing-knife. The slide f moves to and fro in horizontal guides, and is fastened at one end of a connecting rod f', carried by the crank-pin q. In this slide, is mounted a box g, in which the lancets g' are fixed. As the splints are cut, they pass through an opening in the slide d, and through a spout h. Fixed to it, a pair of rollers h' work between guides i' fixed to i, which, at its other end, is hinged to the standard j. The upper side of the spout and trough are covered by an indiarubber band i'', fixed to the slide d and standard k, through an opening by which the splints pass out of the trough and over the table. By these means, the splints, as they are cut, are kept in correct position, and are delivered on the table at the lower end of i. The block of wood A is placed upon the table, pressed towards the slicing-knife c by the block l, and held in position between guides n n'.

The arrangement of the holder for the lancets, and the devices for keeping the wood in position whilst being cut, having been found somewhat inefficient, Pace has devised modifications of these details. Figs. 962 and 966 show elevation and plan of the tool-holder, and Figs. 963, 964, side elevation and plan of the devices for steadying the match-wood. In Figs. 960, 961, a is a portion of the slide carrying the lancets *b*, mounted in a holder *c′*, formed on a lever *c*, which turns upon an axis carried by the slide; this lever *c* is acted upon in one direction by a spring to carry the lancets out of action, whilst an incline *e′*, mounted on an axis, acts reversely to carry the lancets into position for work; *e′* is operated by a tail-piece, which strikes against the framing of the machine, and thereby causes the lancets to come into or out of position for work as required;

960. 962. 963.



961. 964.

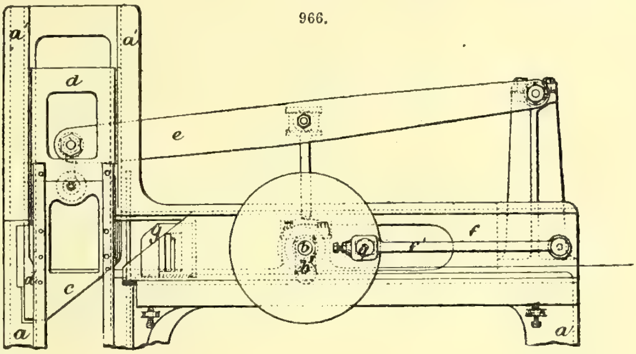


965.

while A, Figs. 963, 964, is the block of wood to be cut into splints. This last is supported on the table *g*, and is pressed forward by the pushing-block *h*. The block is guided at its sides by the fixed guide *i* and adjustable guide *j*, and, at the top, by the holding-down lever *k*; but instead of acting upon the holding-down lever *k*, by means of a locking-latch mounted on an axis of motion at one side of the block of wood, as in Figs. 962, 965, a much longer locking-lever *l* is employed, mounted on an axis *l′*, carried by the holding-down lever *k*, and each end of which comes under inclined catches *m*, fixed to the frame of the machine on each side of the block, and as far therefrom as practicable. By these means, A is held firmly, and the lancets are prevented from following the grain of the wood, and thus made to act with precision.

In Sweden, the splints are usually made from aspen, cut in logs of 12–22 in. diameter. The wood is worked as soon as possible after being felled; if seasoned, it has to be steeped in water. The logs are cut by a cross-cut saw into pieces of 14 in., each containing seven lengths of matches, the bark being removed immediately afterwards by hand labour. The pieces are next chucked in a spear-lathe, making 15–20 rev. a minute, where they are reduced to shavings by a planing tool acting simultaneously over the whole length. The thickness of these shavings is equal to the required thickness of the matches. Fixed to the same rest as the planing tool, but slightly above it, are eight cutters, which divide the shaving into seven equal breadths, whereof each corresponds to the length of one match. These shavings are freed from knots, and cut into lengths of about 6 ft., from which the matches are produced by a machine similar to a guillotine paper-cutter; this operates upon two packs at once, each consisting of 90 shavings, and, when properly fed and making 120 strokes a minute, cuts matches at the rate of a million to each working hour.

966.



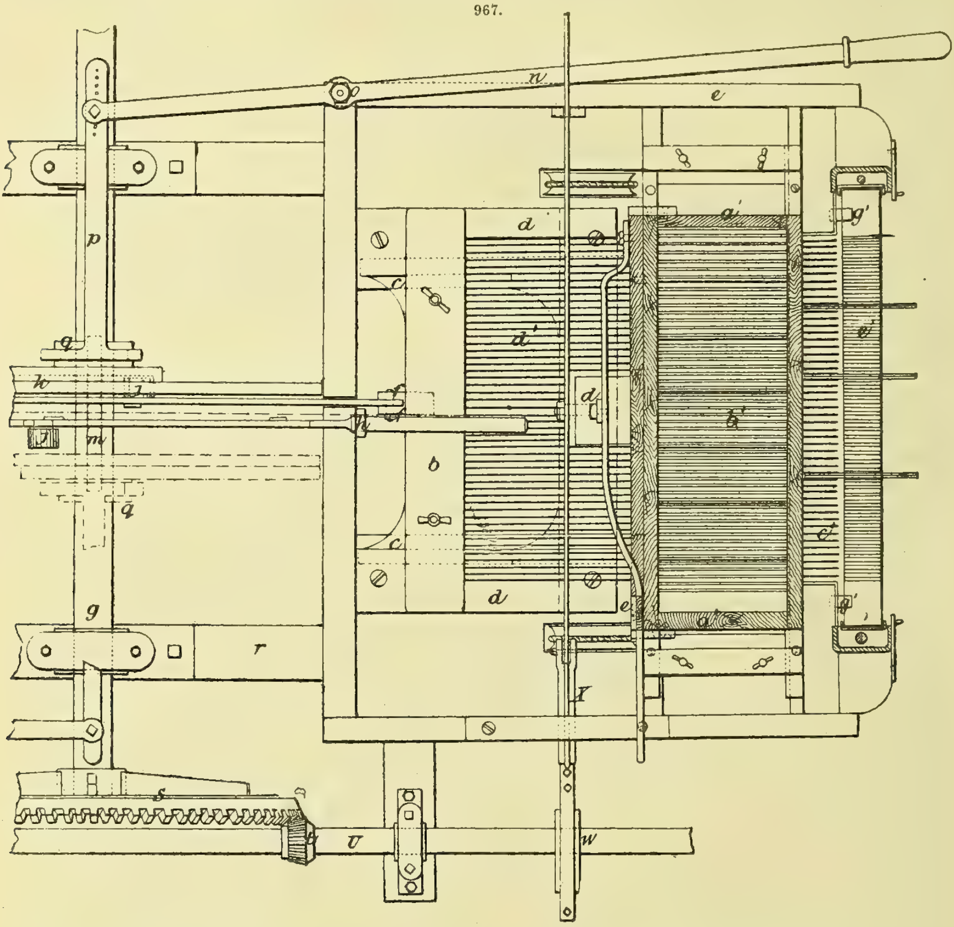
At this stage, the Swedish splints are dried by being passed through two wire-gauze cylinders, about 10 ft. in length and 30 in. diameter, making 30 rev. a minute, and placed one above the other within a brick stove heated by chips and waste. The dried slips are next freed from splinters by being placed on a grid, with openings of suitable width to effect the separation. This grid receives a rapid vibratory motion, in a direction across its openings, by a crank-shaft. Its surface is partitioned, by strips of zinc in the same direction, into compartments a little wider than the length of a match; so that the slips are not only freed from splinters by rubbing against each other and against the bars of the grid, but are also laid parallel in these compartments.

Filling and Dipping.—The splints are then collected into bundles and dried, which takes a longer or shorter time, according to the state of the atmosphere. The next process is to place them in the dipping-frames; the bundles are packed and looked over for "flakes"—imperfect splints, which would interfere with the action of the machine, and must be removed. The general plan was to dip the bundles (before arranging them in the frame) into paraffin. The objectionable feature is that each match does not receive its fair share of paraffin; this is in a great measure obviated by dipping in the frame, or by applying a hot plate to the end of the bundle, which dries the tops of the splints, and enables them to absorb the paraffin with rapidity. Both plans are in use.

The dipping-frame consists of wooden laths, 1 in. by ¼ in. section, and 28 in. long, having a hole at each end, and moving freely upon two round iron bars fixed in a somewhat stronger lath. Between each two of these laths, 50 splints are ranged, equidistant from each other, and projecting equally beyond the surface of the frame. This is done by means of a filling-machine, consisting mainly of a cast-iron table, fitted with 50 parallel grooves, of a depth equal to the intended projection of the cuttings beyond the surface of the frame.

Filling-machines are commonly worked by hand, the frame being held in front, the box containing the splints being shaken by hand, whilst the wires which project the splints from the grooves into the filling-frame are worked by levers from a treadle. Fig. 967 represents a plan of an ordinary filling-machine, with certain additions devised by L. Mount, for enabling a number of machines to be operated simultaneously. Here one machine only is in work, but the Fig. indicates the method in which the two machines, back to back, are driven from the same shaft *g*; and Fig. 968 shows the manner in which the bevelled slide is drawn backwards and forwards, and the length of stroke given by the movement to the stud and roller, and consequently the connecting-rod, by the rotation of the cam; *a* is the connecting-rod, secured to the slide *b*, which is bevelled at its ends *c*, and works in V-grooves in the cast-iron piece *d*, screwed to the frame of the machine *e*. The connecting-rod *a* is secured to the slide *b* by being passed between two tongue-pieces *f* and a bolt. It is made in two parts, fastened together by a strip of metal, and is slotted as in Fig. 968, so that it slides easily over the shaft *g*. Its outer end, shaped in a turned rod, works in the bearings *h*. The connecting-rod is provided with a stud *i*, encircled by a friction-roller *j*; *k* is the cam, with a groove *l* on its face. It is carried round on the shaft *g* by a key *m*, entering a similar sized cavity in the inner periphery of the cam, large enough to allow the cam being operated by the hand-lever *n*, pivoted at *o*, so as to slide along the shaft and out of the way of the friction-roller *j*; *p* is the fork, entering a groove in the boss *q* of the cam, and connected with the hand-lever; *r* are the bearings, placed between the backs of two machines, and on which the shaft *g* is supported; *s* is a bevel-wheel, in gear with a pinion *t* on the shaft U; there are bearings to support this shaft; *w* is a boss, set eccentric on the shaft U, and which, by means of the fixings and attachments *d*, gives a rapid to and fro motion to the hopper *a'* containing the splints. This has the effect of shaking them down into the grooves *b'*, made in the bed-plate forming the bottom of the box *a'*; *c'* are the vertical plates, through which the splints issuing from the machine are separately pushed by the wires *d'* into the grooves of the dipping-frame *e'*. This frame *e'* is set upon the ascending and descending frame, which is controlled in its working by a counterbalance weight. The frame *e'* is prevented from being pulled up by the weight by means of the counterbalance catches *g'*. Motion is imparted to the shaft *w* by means of a belt from a main shaft. This communicates motion through the pinion *t* to the bevel-wheel S and shaft *g*; which latter, by means of its fixed key *m*, carries around the cam *k*, the

967.



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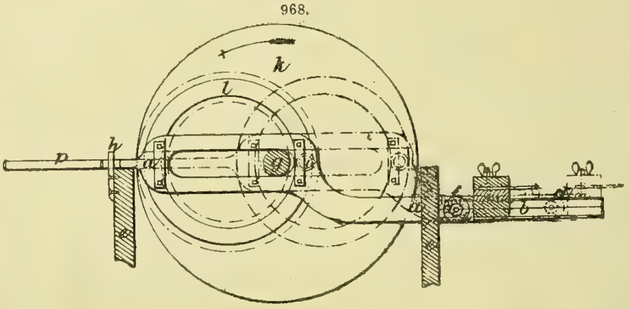
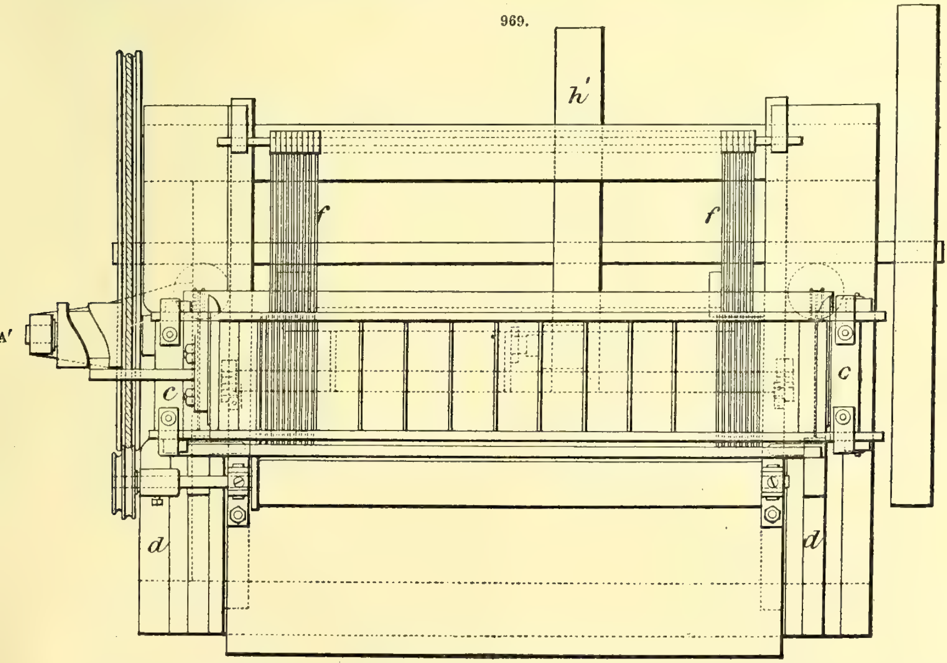


hand-lever *n* having first been moved so as to allow the groove of the cam to admit the friction-roller *j*. The motion is imparted thereto and to the connecting-rod *a* and slide *b*, which last is pushed backwards and forwards; the wires *d′*, entering the grooves *b′* of the bed-plate, push out the splints, which are caused to fall by the shaking or to-and-fro motion imparted to the hopper, between the plates *c′* and on to the fold of the dipping-frame; another grooved fold is then put on the same, and the operation is continued until the dipping-frame is filled, when it is taken away and a fresh one is supplied. The rotation of the shaft *u* carries with it the fixed eccentric boss *w*; this is connected with the jawed connecting-rod *x*, and this latter to the bar *x′*. The motion is imparted from this to the pieces *y*, and to the hopper. The lower of these pieces is fixed to the rod *x′*, and the upper one is attached to the iron band *x″* of the hopper. They are held together, when required, by means of the drop pivoted bit *y″*, worked by the rod *z*. An additional groove is formed at either end of the bed-plate, so that if more than the proper number of splints should fall into the grooves *b′*, they will be kept from being pushed out of the box, and thus overcrowding the dipping-frame and wearing out the brush. The shafts *g u* and the rod *X′* can be continued or lengthened, so as to accommodate and work any convenient number of machines.

The filled frames are conveyed away to be dipped. They are placed on a flat table, and levelled by taps upon a piece of board. Matches were formerly all tipped with sulphur to convey the flame; but this is now done only when, for economy's sake, the sweepings of the factory are re-dipped, and these are sold as inferior goods. If not already paraffined, first one side and then the other is immersed and withdrawn from the paraffin-bath; they are then passed on to the dipping-room. The apparatus here consists of a steam-jacketed iron pan, containing the igniting composition, and a hollow iron table, also kept hot by steam, upon which a sufficient quantity of the composition is from time to time ladled to supply the requirements of the work; this is spread in the necessary thickness, and to cover a space somewhat larger than the dipping-frame. The splints projecting from one side of the frame are applied to the composition for a moment, and, in the case of common matches, are removed, reversed, and applied at once to the other side; but with good matches, after one side is dipped, the frame is suspended, and dipped end downwards for some 15–20 minutes, being slid between light iron supports provided for this purpose at the sides of the dipping-room; the composition thus assumes a more sightly form, and the top of the match is well rounded, the other side of the splint being completed in precisely the same way when the first is dry.

969.

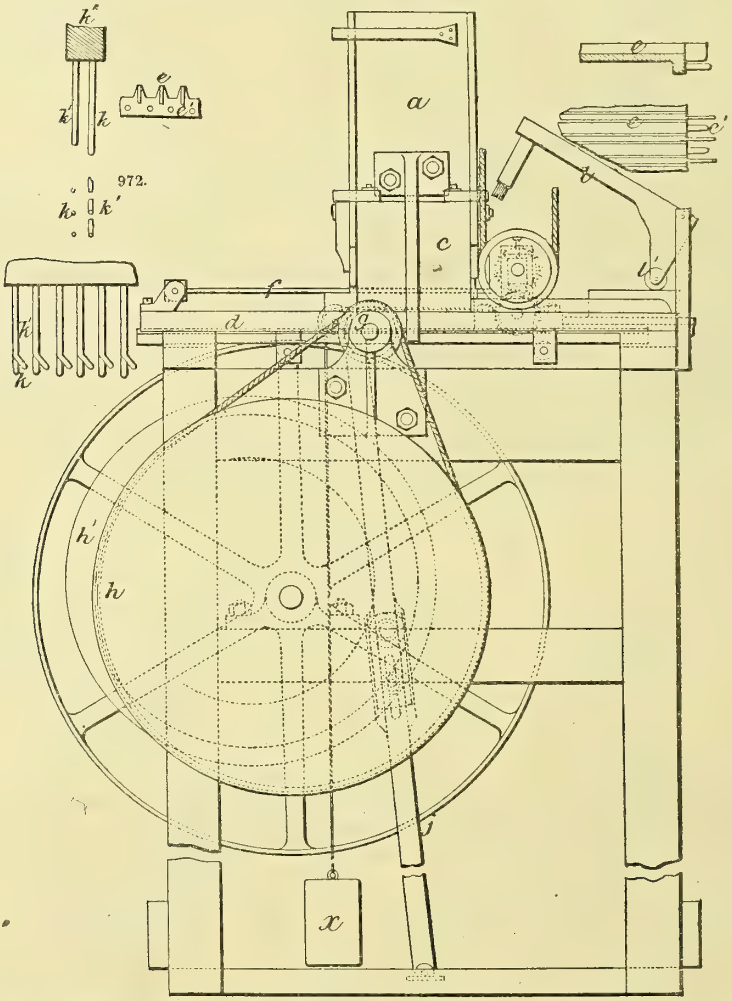


970.

The matches are finished by being removed in the frames to a drying-room, where, after remaining for a short time, they are ready for cutting and packing into boxes.

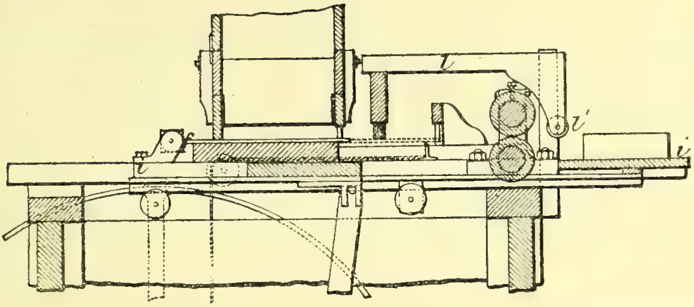
The matches, when dry, are laid in heaps, cut down, and put into boxes by the handful. The boxes, when filled, are placed in frames called "ducks," holding three to four gross, and passed through iron doors into the packing-room, where they are put into packages, glued up, and labelled.

It has been supposed to be advantageous to point the ends of splints before dipping, and to effect this economically, Pace has devised the machine shown in Figs. 969 to 976. In manufacturing pointed splints, he first sorts them, so as to get rid of all short or otherwise imperfect ones. For this purpose, machinery such as that represented in end view Fig. 973, vertical section Fig. 975, plan Fig. 969, and side view Fig. 976, is employed. The splints are placed in a reciprocating box *a*, provided with projections, working on guide-bars *b*. The box *a* is prevented rising from *b*, by guide *s*, fixed to standards *c*, carried by the table *d* of the machine, and adjusted sideways by guides *a″*. The box *a* is provided with divisions, and the bottom is formed by a fixed plate *e*, provided with grooves *e′* to receive the splints. A series of wires and rods *f* mounted on a rod *f′* act in combination to push the splints out in a manner similar to the filling-machine, Fig. 967. An arm A′ has on its end a roller C′, running in the groove of a cam *g*, provided with axes working in bearings fixed to a bracket. This cam receives motion by means of a belt passing partly around a grooved pulley on one end of *g*, and partly around a grooved wheel *h* on the driving-shaft. By these means, an endwise reciprocating motion is given to the box *a*, in order to agitate the splints. The rod *f′*, with the pushing-wires, is carried by brackets fixed to a table *i*, which has a reciprocating motion derived from a lever *j* mounted on the frame, and provided with a pulley, working in the groove of a cam *h′* fixed on the driving-axis. The grooves *e* (Fig. 974)

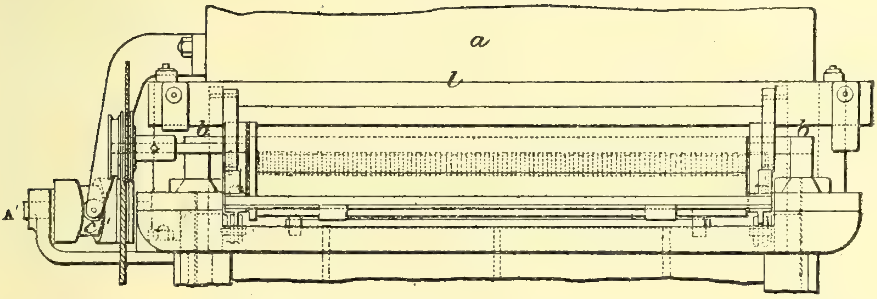

971. 973. 974. 972.

extend a short distance beyond the front of *a*, and, at their ends, the bottoms are removed, and replaced by short pins *e'*, occupying only a portion of the width. In connection with *e*, are sliding supports, Figs. 971, 972, 975, consisting of straight wires *k* and bent wires *k'*, the latter turned at their points, so that these partially cross the spaces between the wires *k*. Both *k* and *k'* are fixed in a bar *k,"* joined to the slides, which move to and fro in grooves, formed in the table *d*; they are forced in the one direction by weights *x*, and in the other, by pushers *i"*, which also act upon projecting plates *k"* fixed to the slides. Thus the reciprocating supports *k k'*, the travelling bed *i*, and the pushers *f* travel together in the one direction until the travelling supports *k k'* arrive at the box *a*, when the travelling bed *i* and pushers *f* continue their motion a short distance, and the motion of the travelling supports *k k'* is stopped for a time; then, on the return journey of the pushers *f*, the latter travel for a short distance alone; and finally, the pushers and the travelling supports *k k'* move together for the remainder of the distance.

975.



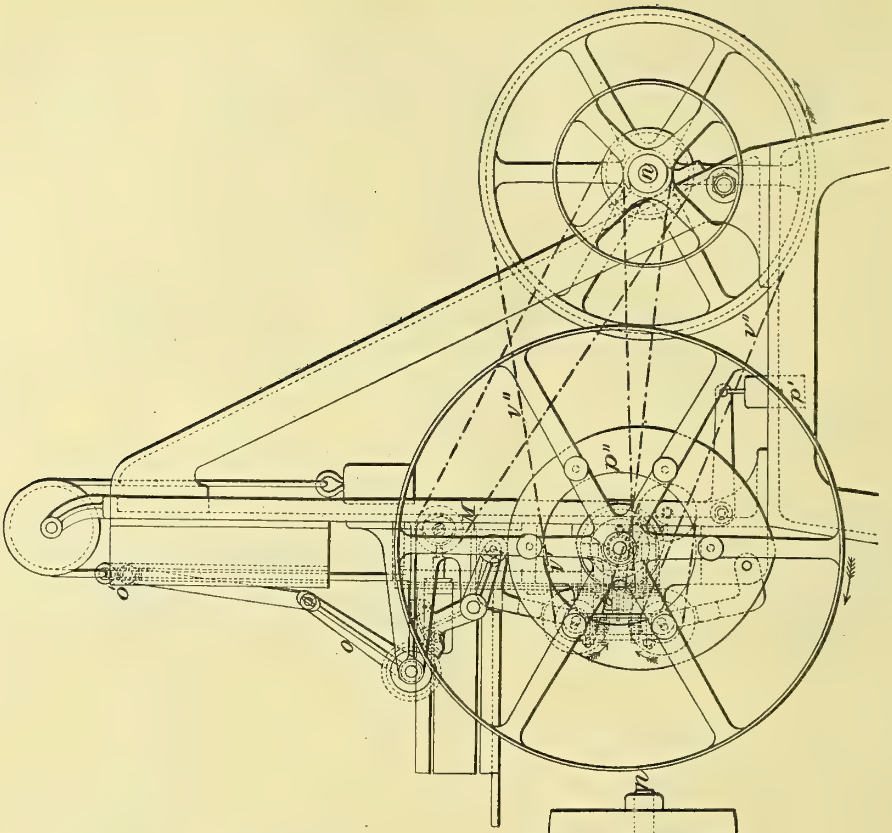
976.



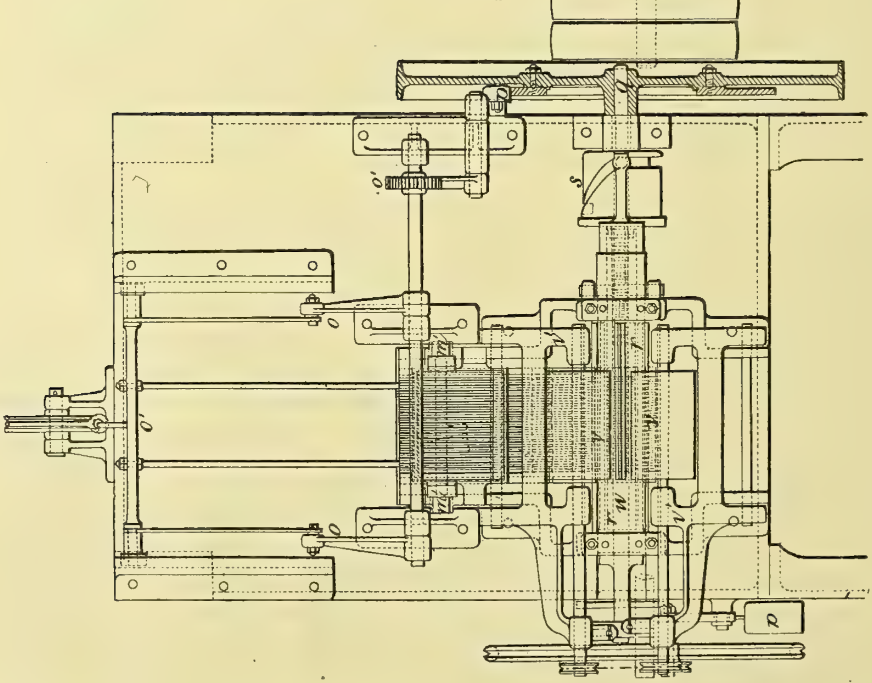
As the splints are pushed out from *e*, and fall on to *e'*, a brush *l* descends, and brushes aside the faulty splints. This brush is fixed to a lever *l'*, mounted on to a fixed axis. The tail of the lever *l'* is acted upon by a projection, fixed on the travelling bed *i*, so that, as the projection approaches the box *a*, it acts upon the tail-piece *l'*, and raises the brush *l* to permit the required motion of the sliding supports *k k'* to ensure the proper drawing off of the selected splints. These drawing-off rollers are covered with indiarubber, mounted in bearings, and rotated by a strap from an intermediate wheel, motion being communicated from one roller to the other by toothed-wheels. Thus any short or faulty splints will fall down, whilst the good splints will remain supported by *e'* and *k k'*; in the return motion of the travelling bed *i*, the splints will be taken by the delivery-rollers.

The splints, sorted in this manner, are fed into a box *m* forming part of the pointing-machine, a plan of which is represented, with the pointing-rollers removed, in Fig. 977, a front view in Fig. 979, and an end view in Fig. 978. Fig. 982 is a vertical section of parts on the line A B of Fig. 977. The bottom of the box *m* is formed by a fixed grooved plate, and is provided with V-pieces *m'*, sliding in guides; to these pieces, is fixed a cross-bar, having at its centre a roller which works within the groove of a cam M, mounted on a cross-shaft turned by a strap, which passes partly around a groove formed on the boss of the cam M, and partly round a pulley fixed on the driving-shaft. The splints are placed in the box in a vertical position, and are pressed towards the bottom by wires, which work in slots formed in the sides of the box *m*, and are acted upon by springs. The splints are, by means of wires, carried by a reciprocating-bar, pushed from beneath the box along continuations of the grooves, and in their course from beneath the box *m*, are first acted upon by

978.

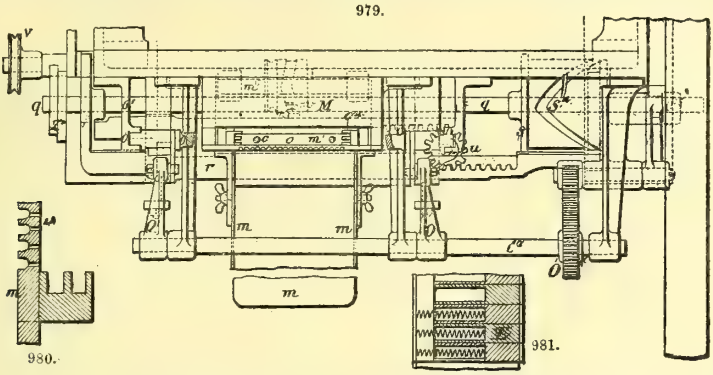


977.



spring-pistons E, Fig. 981, to retain them in the grooves, and then, before they have left these pistons E, pressure is applied to them for a similar purpose by a series of springs carried by a fixed bar. The spring-pistons also prevent more than one splint passing from a groove at each action of the wires. The bar *o* is fixed to the lower ends of rods, which, at their other ends, are fixed to a cross-bar O′, whose ends work within channels formed in the frame of the machine. This cross-bar is connected with levers O, fixed on a shaft, which bears a toothed-wheel *o*′, receiving motion from a toothed segment formed on a lever, whose bearing is connected with a second lever, provided at its end with a roller *p*, resting on the periphery of a cam *p*″. This cam *p*″ is fixed to the arms of a wheel on one end of the main driving-shaft *q*. A weight hanging from one end of a cord passes over a pulley, is connected at its other end with the cross-bar O′, which it raises, at the same time keeping the roller up to its cam *p*″.

979.



980.

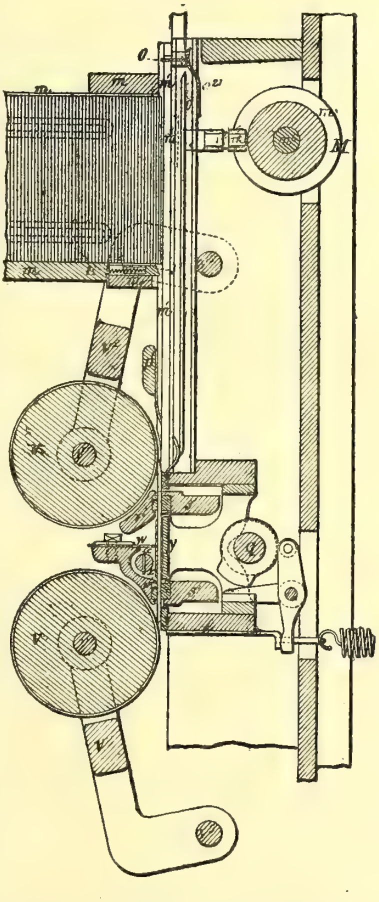
981.

In the further descent of the splints, they fall between reciprocating rubbers, and are correctly adjusted by a catch-plate, which is simultaneously pushed forward to receive the lower ends of the splints. The rubbers are fixed in frames *r s*′, which slide a short distance away from the splints, so as to leave a free space for their descent. The frame *r* is acted upon at each end by cams *s*″ on the main shaft, to remove the rubbers from the splints, and by springs to press them inwards.

From one end of the frame *r*, projects a stud, provided with a roller, working in the groove of a cam *s*″, and the frames *r*′ *s*′ have toothed racks taking into the teeth of a pinion *u*; thus as motion in the one direction is given to the second frame *r*′, a similar motion, but in the contrary direction, is given to the second frame *s*′, and consequently the splints held between the rubbers *r s* are rotated first in one direction and then in the other.

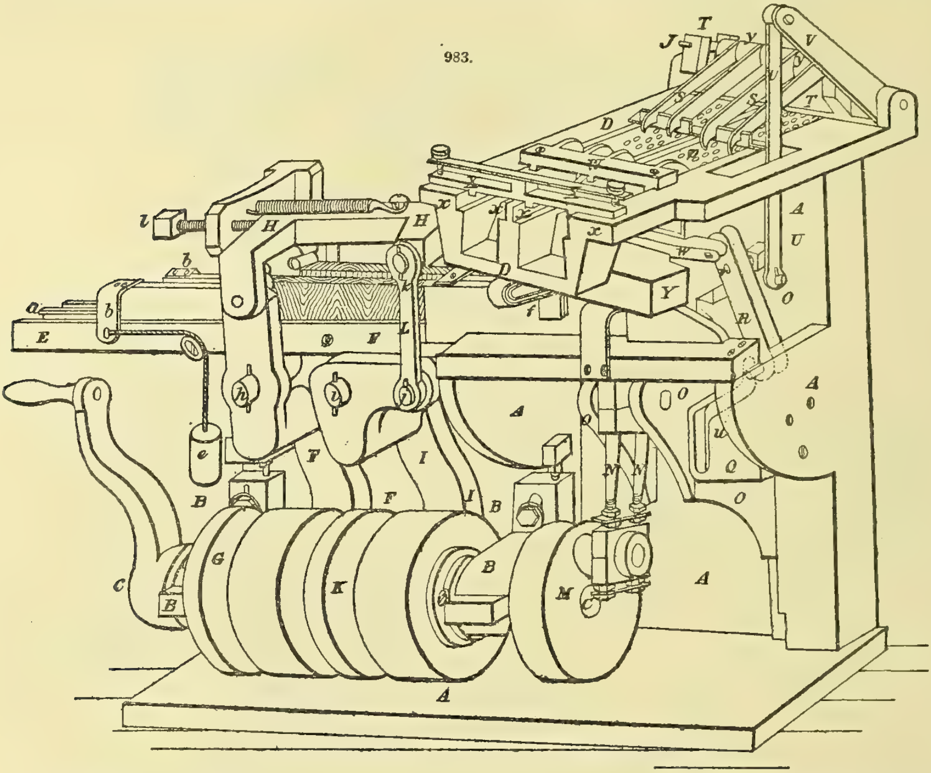
During the rotation of the splints, their ends are acted upon by pointing-rollers *v*, provided with cutting surfaces. The axes of these rollers are mounted in frames *v*′, and on axes to which motion is given by a strap V″, passing partly around a wheel fixed on the shaft *n*. These pointing-rollers *v* are removed from contact with the splints by means of cams, acting upon adjusting-screws, carried by the frames V′; and the pointing-rollers are taken into position by the weight *p*′, acting through a lever, carrying a tension-roller upon the band V″. A blade *w* is mounted in the frame *r*, in order to cut the double splints nearly into two. To facilitate the discharge of the pointed splints from the machine, a wiper *x*, consisting of a strip of indiarubber mounted between the two halves of a shaft, is employed to act upon the splints.

982.



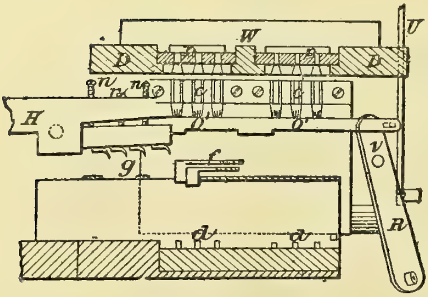
Machinery is much more employed in this manufacture in the United States than in Europe, and, with the exception of splint-cutters and common filling-machines, most of that here described is due to American ingenuity. Figs. 983, 984, 985, show McC. Young's cutting- and filling-machines.

983.

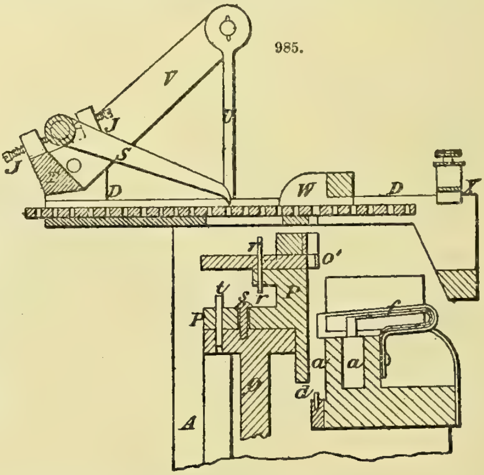


The main frame A is made very strongly of cast-iron. In bearings B is hung the shaft C, and on it are arranged a series of cams and cranks. On the top of the main frame A is secured the secondary frame D, set obliquely. To the main frame, is joined a feeding-trough E, in which are

984.



985.



two guideways *a a*, for containing the blocks of wood from which the match-splints are to be cut. Behind, is a feeder *b*, to which is attached a cord, passing over a pulley, and having upon its end a falling weight *e*, by which the blocks are fed up to the splint-cutters. A spring *f* is arranged to press upon the foremost of the series of blocks, to prevent them from slipping back when the feeder *g* is out of the wood, and recedes to take a new hold. The weights *e* move the blocks up to the real feeder *g*, and the latter forces the blocks along to the cutters. The two toothed feeders *g* are arranged side by side, so that each one feeds up its own line of blocks. A lever F is pivoted to the main frame at *h*, and, upon its lower end, is a friction-roller that runs in an undercut cam-groove G on the cam-shaft C, so that F has a positive motion in both directions. To this lever F, are attached, by a cross-arm, arms to which is pivoted the rear of the frame H that carries the feeding-points *g*; by this arrangement, the forward and backward feed-motions are attained. Another lever I, pivoted to the main frame at *i*, has upon its lower end a friction-roller, running in an undercut cam-groove K on the cam-shaft C, by which it also receives a positive vibratory motion. On the lever I, is a crank-arm, to pivot pins *j*, in which the lower ends of connecting-straps L are attached, the upper ends of these straps being pivoted at *k* to the frame H, which carries the feeding-points *g*; by this mechanism, the feeding-points receive their upward and downward motions. An adjusting-screw at *l* regulates the backward movement of the frame H, and consequently the length of the feed. The spring *m* holds the frame H to its bearings.

On the end of the shaft C is a crank-wheel M, to a wrist in which is joined the pitman N, whose upper end is attached to the vertically reciprocating frame O, carrying the series of knives *o o* and *o′ o′*. The cutters and the knife-frame are set obliquely to the line in which the blocks are fed, both sets cutting and moving at the same time. Above *o o′*, are guides *c*, partially open, to allow small slivers of wood to pass out, and thus prevent clogging; above these guides *c*, is a guide-plate with countersunk openings, by which the splints are guided into the holes of the moving plates *p*, and carried out of the machine. The points *d* hold the wood to form the splints, and allow the cutters to go clear through, and entirely sever the splints from the blocks, these points entering slightly into the cutters for that purpose.

The cutters *o o′* are made upon the ends of small steel bars; each of these has a seat in the knife-stock, into which they are slipped from the rear of the machine. They are held in exact position in relation to each other, and to the blocks of wood they are to act upon, by pins *r* passing through them into the stock; they can therefore be drawn out or replaced with great accuracy. The stock P is made adjustable on the gate O by a slot and set-screw as at *s*; to hold it in position, steel pins *t* pass through the stock and into the gate. At times it may be necessary to redrill and enlarge the holes and the pins *t*, when the stock, by wear, has to be moved up any material distance; for this purpose, these parts are so made as to be readily reached.

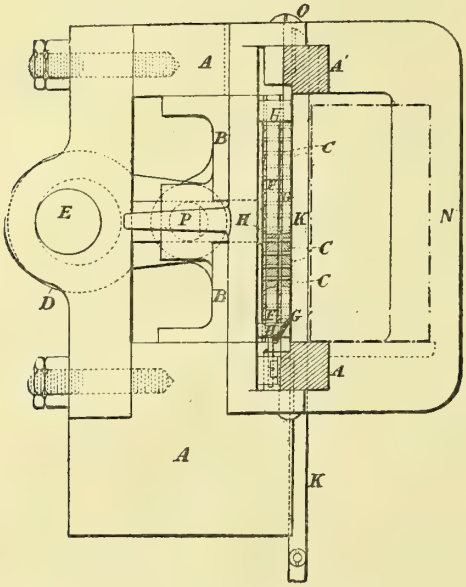
In a plate Q attached to the main frame, is a cam-slot *u*, in which runs a roller on the end of the lever R; this lever is pivoted to the gate at *v*, and is vibrated by the slot. To the upper end of R, is pivoted the sliding keeper-plate *w*, which, when the splints are in the cutters, guides, or carriers, and are being carried up to be stuck in the plates P, moves underneath and forms a support for them, forcing them into the plates P. In ways *x* in the carriage-frame D, the two plates *p* are moved by feeding-fingers S, which take into the holes in these plates, and so push them along in exact time to receive the match-splints as they are brought up to it. These fingers S are loosely arranged upon a shaft with washers *y* between them; this shaft is hung in a rocking-box T, by screw-points J, diametrically opposite to each other, and at each end of the shaft, so that the shaft and the fingers may be adjusted with precision, as the holes in the plates *p* must be exactly over the splints, and at the exact time to receive them, the machine being run at a very high speed. The box T is rocked from the gate O by means of the connecting-rod U and arm V. The plates *p* are connected together, fed along in an endless series, and separated after they come out filled with match-splints for convenient handling. On the frame D, is placed a rigid presser-bar W, bearing upon the plates *p* near the points where they are receiving the splints; and near the end of the frame D, is a yielding presser-bar X, for holding the plates to the ways, and against accidental movement.

The set-screws *n* are for defining the extent to which the feeding-points *g* shall enter the wood, and to compensate for their wearing away. At Y, is a wind-trunk, through which an exhaust-current of air is drawn by a fan, to clear the machine of all small slivers of wood and other material that would tend to clog it.

For the purpose of expelling the splints from the perforated plates after dipping, McC. Young employs the machine shown in Figs. 986 (end view), 988 (plan), and 987 (detail of framing): A is the framing; B in a sliding block carrying punches C, passing through a perforated guide-plate F; D eccentrics on a shaft E for moving the block B to and fro. The shaft has a partial turn given to it by a long lever-arm whenever B is to be moved. G is one of the plates holding the finished matches; it is slid into grooves in top and bottom cross-bars A′, forming part of the frame, and is so brought into position in front of the set of punches. As the plate is slid forwards along the grooves, Fig. 986, it moves freely past a stop H, until its forward end comes against a stop I. The stop H is then, by a spring, caused to turn in behind the rear end of the plate, and prevent it from moving back. When thus held, the holes in G are opposite to the punches.

It requires considerable pressure to simultaneously expel all the matches from a plate, and to support it against the action of the punches. Thin metallic bars K are used, raised or lowered by turning the weighted lever L, Fig. 987, and held in either position by the weight. M are stops. Whilst the plate is being placed in front of the punches, the bars K are in their lowest position. The bars are then raised, one edge of each coming against the plate, and the other against parts of the frame. The block carrying the punches is advanced, and the matches are expelled, and received into a box. To allow the plate to be moved forward, the stop I must be turned aside; the stops I H therefore turn on pins O, and have lever-handles P, by which they can be moved by hand; they are also acted on by a spring Q, to bring the stop into position.

986.



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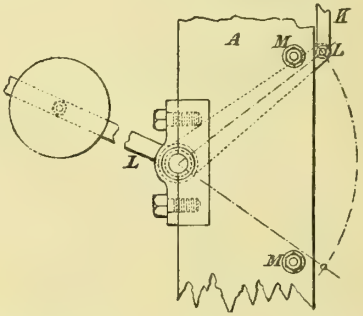
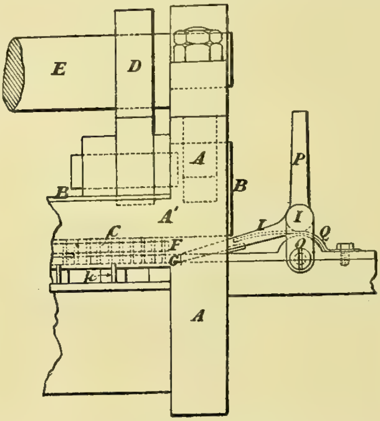


An ingenious machine for filling splints, devised by E. B. Beecher, of Connecticut, is shown in Figs. 989 (plan), 990 (longitudinal section), 991 (side elevation), and 992–994 (details). The frame *a* rests upon a bed-plate, to which the legs of the frame are fastened. On the main driving-shaft *b*, are fast and loose driving-pulleys, and a toothed-wheel which gears it to a counter-shaft *c*, surrounded between its bearings by a sleeve *d'*, attached to the vibratable frame *d*, which swings thereon as its axis, irrespective of the rotation of the shaft. The splint-frame mandrel *x* rotates in a long pipe-bearing *x'*, attached to the end of the frame *d* that hangs over the mechanism for setting the splints. Upon this mandrel, is placed the drum *f*, upon which the splints are framed, this being slipped upon the mandrel at the end and held so as to rotate with it, and be readily removed.

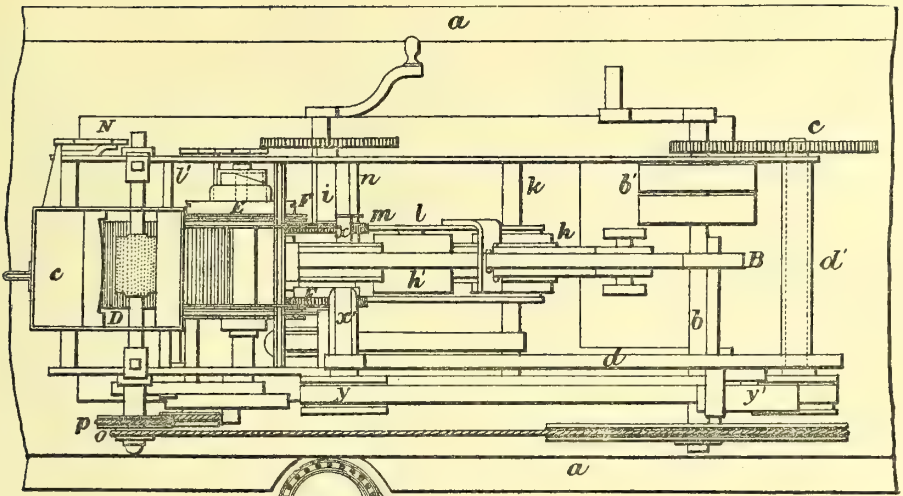
988.



To compensate for the increasing size of the frame, and to maintain a constant tension on the binding-tape, the frame-drum mandrel is driven by a rapidly-revolving friction surface on the mandrel-pulley *y*, its tension being regulated by the adjustable tightening-pulley *y'*. The frame-drum should be about 3 in. in diam., and for two-length splints about 3 in. wide.

The binding-tape A is of cotton-webbing, about the thickness of the splints, some 2½ in. wide, and attached at one end to the frame-drum by winding a coil around the same. The other end of the tape is placed in a coil upon a journal, from which as it uncoils it passes through the guide *s* to a holding mechanism, consisting of an endless band *h*, which is mounted on drums and a weighted pressure-roller *h'*. The coil of secondary tape B is located in a plane above the lower belt, and carried through a guide to the winding-drum. The main tape passes from A upwards, partially around a guide-roller, and thence to the frame-drum *f*. The guide-roller turns loosely on the shaft *i* between two setting-wheels F, constructed with notches the thickness of a splint apart, to take the splints one by one from the count-wheels, at a point above the binding-tape, as it passes over the guide-roller, to carry in the splints regularly between the binding-tape going in to the frame and the preceding coil, the splints being lifted out of the notches of the setting-wheel by the binding-tape; the auxiliary tape is at the same time drawn in over the latter. By this arrange-

989.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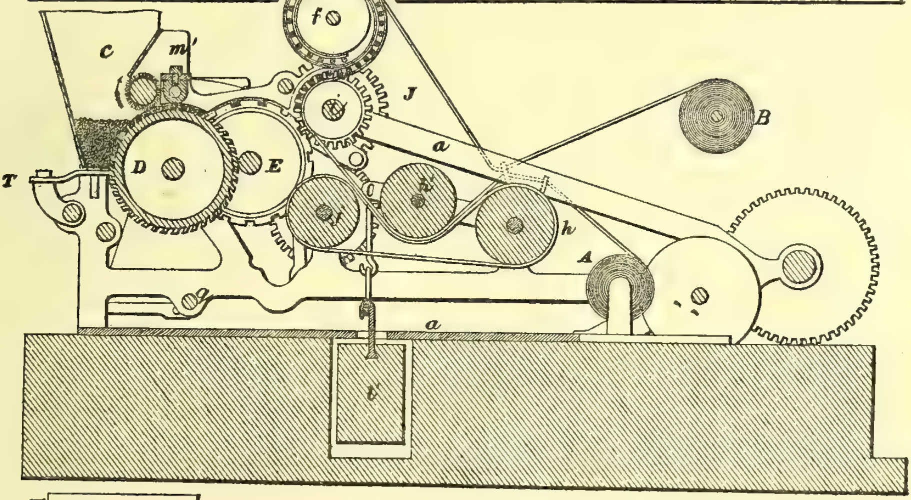
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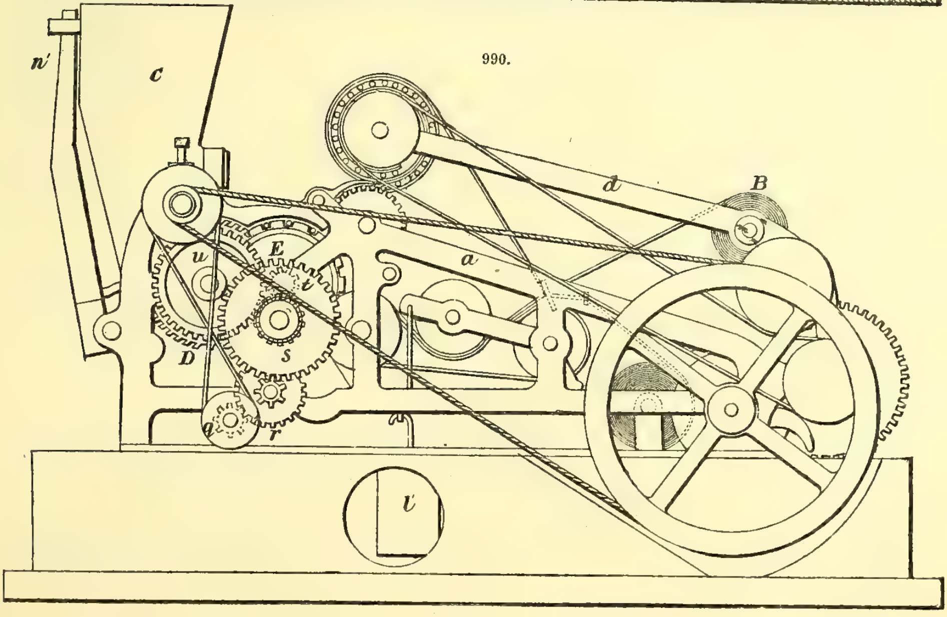
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991.

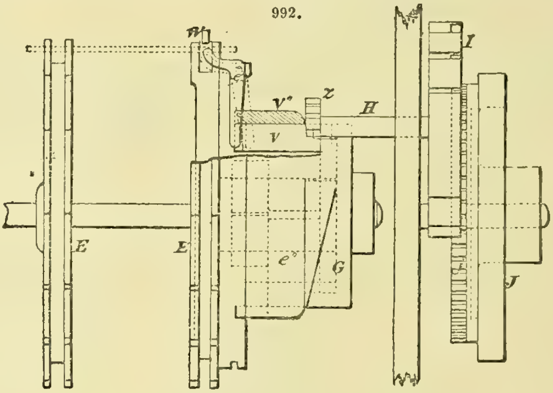
ment, the splints lie between two thicknesses of taping, the order being: (1) the main belt, (2) the splints, (3) the auxiliary belt, (4) the main belt, and so on.

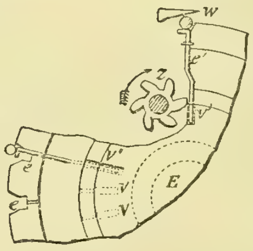
The frame, having been completed, may be removed from the machine, and treated in the ordinary manner. When it is desired to unroll the frame, the upper tape should first be unwound, one turn, for the purpose of changing the relative position of the belts, so that in unwinding them the matches will lie between them. The splint-setting wheels are rotated by a toothed-wheel J on the end of the shaft *i*, which gears into and is driven by a toothed-wheel on the shaft *j*, actuating the holding and feeding mechanism of the binder-tape, so that the setting-wheels and feed-mechanism move simultaneously.

The driving-drum which moves the endless belt *h* is fast to the shaft *j*, and the loose drum runs on a bearing in the middle of the tie-rod *k*, which is fast at both ends to the sides of the machine frame. The pressure-roller *h′* runs loose on a fixed axis *l*, fast to a frame which swings on bearings on the tie-rod at each side of the loose drum, and is connected with a heavy weight *l′* by links.

A rotating wire-brush cylinder, covered with card-teeth inclined backwards, is placed over the receiving-cylinder D, as close to it as possible, and is rapidly rotated in the direction of the arrow, Fig. 990, for the purpose of sweeping from the surface of the cylinder those splints which are not taken into the grooves. There are also curved guides placed over the receiving-cylinder and count-wheels E, and running up in front of the setting-wheels F, for the purpose of keeping the splints in the grooves and notches of these devices. The hopper *c*, which is of suitable width for the splints, is wider than the receiving-wheel, the excess width being equally apportioned at both ends of the receiving-cylinder, so that the splints, when taken into the grooves of the receiving-cylinder, project equally from both ends of the same, in order that the count-wheels may lift them by their projecting ends, and transfer them to the setting-wheels.

992.





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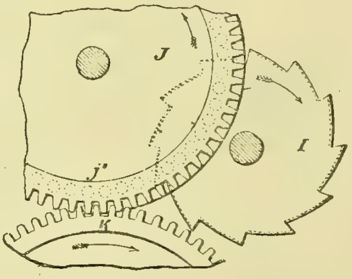


994.

A pair of stationary cams *m*, fast at one end to the tie-rod *n*, come up close to the sides of the setting-wheels, and extend forward with a curve into the groove of the count-wheels. These cams assist in the transfer of the splints from the count-wheels to the setting-wheels, by lifting them from the former at the point of transfer.

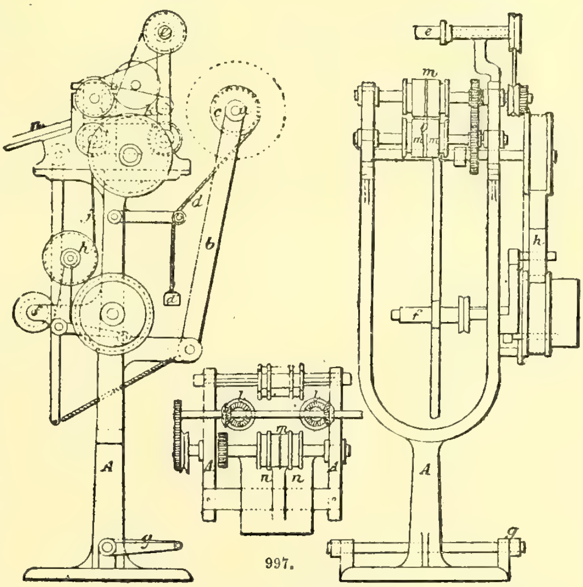
Motion is communicated to the machine from the fly-wheel on the main shaft by a band *o*, running on a grooved rest-pulley fast to the wire-brush shaft, and which, by a groove of larger diameter, drives a cross-band *p*; the latter turns a grooved pulley fast to the shaft *q*, which rotates in bearings on the under side of the frame of the machine. On this shaft, is a pinion gearing with a carrier-toothed-wheel *r*, running on a stud-pin at the side of the frame, and carrying with it a pinion which drives a second toothed-wheel, with a pinion *s*, which gears with the wheel *t* fast to the receiving-wheel shaft, and also with *u* on the count-wheel shaft.

The wheels on the receiving-cylinder and count-wheel shafts, being both driven by the same pinion *s*, must bear the same proportion to each other, as the number of opposite pairs of teeth in the count-wheels do to the number of splint-grooves in the receiving-cylinder. Figs. 992–994 show on a larger scale the connecting and disconnecting mechanism; *e*, Fig. 993, are recesses in the count-wheel E, which receive the splints from the cylinder, and convey them to the setting-wheels; *e′* is one of a series of bent levers pivoted at its angle to studs projecting from the face of one of the count-wheels; a bent end of this lever extends into the recess of the count-wheels, and furnishes a bearing for the match-splint; the long arm of the lever extends inwards toward the axis of the wheel. At *e''*, is seen a block secured to the count-wheel in such a manner as to revolve with it, and which is provided with radial recesses, Fig. 992; *v'* is a shuttle lying in this, and able to move in a longitudinal direction to a limited extent; *v''* is a ring by means of which the shuttles *v'* are securely fastened in their proper position; *w* represents a cam arranged over the count-wheel.

By the fixed cam-piece G, the shuttle-pieces are moved in one direction. The shaft H is supported in bearings, and provided at one end with a pinion *z*, whose teeth engage successively with the projecting ends of the shuttles when the latter are thrust out of the casting. On the other end of this shaft, is the check-wheel.

The count-wheels receive in the recesses *e* the splints from the cylinder D. As these pass beneath the cam *w*, the short arm of the lever *e'* is depressed, and the long arm is moved, causing the shuttle to slide outward. The latter thus projects into the plane of movement of the pinion *z*, and serves as a cog to give it movement for a determined distance, by which the setting-wheels are moved through the intermediate connecting mechanism to a corresponding extent. If, however, a splint is wanting, the lever *e'* is not actuated, and no tooth is presented to engage with the spur-wheel. As the latter remains stationary, the setting-wheels of the winding-band will not be moved, and consequently no vacant spaces are left in the frame.

The shuttles, after being thrown out to engage with the spur-wheel, are returned to their former position by the action of the cam G, against which they are carried by the continued revolution of the wheel. The check-wheel I, Fig. 992, the end of shaft H of the spur-wheel *z*, is a disc, having its periphery provided with a series of inclined planes overhanging upon one side. The check-wheel I engages with a wheel K, which actuates the mechanism for holding and feeding the main tape. J is provided with a series of pins *j''*, which lie in the plane of the movement of the check-wheel I, the construction being such that this wheel J can only revolve as its pins are successively driven or released by the revolution of the wheel I. With these parts so constructed, all the movements of the spur-wheel will be positively communicated by the check-wheel to the setting and framing mechanism; but the force applied to turn the frame-drum cannot be exerted through the connecting-mechanism to turn the check-wheel, when the latter is stationary. The shaft of the check-wheel should be set at such an angle, that its inclined planes will engage with the pins of the gear-wheel at one point only. The hopper *c* is pivoted in front to a seat upon the tie-rod *l'*, to which it is confined, so as to vibrate freely by the screw-pin *m'*; it is also supported behind near the top by being jointed to a long elastic rod *n'*, fast at the lower end of the tie-rod. A shaking motion is given to the hopper by the bell-crank T, connected by a link N with the lever, and playing between the pins projecting from the bottom of the hopper.


995. 996. 997.

After being dipped, the splints have to be unwound, and cut at the middle. This is effected in the machine shown in Figs. 995–997: A is the frame of the machine; *a*, a shaft on which the coil of matches is placed to be unwound; *b*, an arm carrying *a*; *c*, a tension-pulley operated by the strap *d* and weight *d'*; *e f*, shafts on which the webs of the coil are wound; *g*, a treadle; *h*, a pulley connected with it, and serving for tightening the driving-belt; *k*, endless bands; *l*, guiding-discs covered with indiarubber; *m*, a revolving cutter, fitted between two blocks, and working above similar blocks *m'*, which are provided at *o* with some soft material for the knife to work on; *n* wires for keeping the matches in place. The circular bundle, consisting of matches held between webs, is placed on the shaft *a*, and the operator, taking the ends of the bands of the coil, places one of them round the shaft *e*, and another round *f*. The machine being set in motion by depressing the lever *g*, and so causing the pulley *h* to press against the driving-strap *j*, and tighten it, the web is unwound from the coil, and wound upon the shafts, leaving the matches between the endless bands *k*, which carry them between two revolving discs, and forward under the cutter *m*, which divides them in the centre. The discs present the splints to the cutter in such a manner as to ensure their being divided into equal lengths, and during this operation, they are kept from flying out of place, by two wires *n*, and are finally delivered into a trough, ready to be put into boxes.

Vestas.—In making wax vestas, the first process is the coating of the cotton. A number, say 20, of strands or wicks, composed of 15–20 threads each, are led from a bale placed upon the ground through guides arranged overhead, down into an oval steam-jacketed pan, filled with wax composition, underneath a presser arranged in the centre of a pan, and through a draw-plate pierced with holes of the required gauge of the match-body; thence it is led some 15–16 ft. over a drum 5–6 ft. in diameter, and then to a similar drum on the opposite side of the bath, from which it is repeatedly passed through the paraffin, wooden guides being arranged to support the wick whereever necessary. The distance traversed after the cotton has passed through the bath is made as long as possible, since the composition neither dries so readily, nor adheres so uniformly to the strand, as in the after-dipping. It is passed and repassed about six times through the bath, until the wax coating is of sufficient thickness, and just passes the holes in the gauge-plates. Considerable care is necessary to ensure evenness in the first coating, and to watch against broken threads.

The drum has a metallic plate on one part of its circumference, and here the wax taper is cut into lengths of the circumference of the drum, is tied in bundles, and is carried to the table having partitions to hold each bundle of lengths. The lengths are pressed against a gauge, and cut up by means of a knife working on a pivot. The match-bodies so cut off are carefully transferred to shallow zinc frames, constructed of the required depth, and made with a lid which is slid down when the frame is filled; they are then carried to a filling-machine similar to that shown in Fig. 967, but of a smaller size, and usually worked by hand. Here they are filled into dipping, frames in the same way as ordinary matches, the machine having its hopper arranged to suit the size of the bodies. Wax matches can be dipped in the same way as those of wood; but some years since, S. A. Bell devised a machine in which frames are attached to two chains running on either side of guides. Between each, a flannel roller revolves in a pan of liquid composition. The frames with the splints arranged downwards run over this roller, and the composition is thereby added to the bodies with considerable regularity and dispatch. The machine will dip 3500–4000 frames a day, and since each frame holds about 4500 splints, it will dip about 18,000,000 splints in that time. The drying is effected, when practicable, in the open air, the frames standing together in twos or fours. At other times, the splints are dried by hot air, distributed by means of revolving fans, in rooms set apart for the purpose. After drying, they are sorted and packed in boxes of various size, pattern, and capacity.

Vesuvians.—The "vesuvians" principally used as lights by smokers, have rounded splints, made from alder, or some similarly hard wood, the object being to prevent the ignition of the wood, and consequent dropping of the burning composition. The more expensive kinds are made on glass bodies, consisting of glass piping of small section (see Glass, p. 1072), which is chiefly procured from Italy, and should yield some 1200 splints to the lb. J. W. Hunt and Co., of London, have an ingenious method of retaining the composition by means of a piece of wire, about $\frac{1}{3}$ in. long, inserted by hand into the end of each splint; it answers the purpose effectually. The vesuvian-splints are placed by hand into the dipping-frames, dipped twice or three times into the burning-composition, until the head is of sufficient size, and then finally dipped into the igniting-composition, in the same way as an ordinary match, an interval being allowed between the operations for drying.

Compositions.—Igniting-compositions are generally manufactured of some form of phosphorus mixed with oxidizing agents, with which it will readily inflame by friction. Such are saltpetre, chlorate of potash, and red-lead; these are mixed up with glue, which causes them to adhere to each other and to the wooden splints. Most makers have a particular mixture of their own; the following practical recipes may be taken as fairly representative, the first being the best:—(1) $\frac{1}{2}$ part by weight phosphorus, 4 chlorate of potash, 2 glue, 1 whiting, 4 finely-powdered glass, 11 water; (2) 2 parts by weight phosphorus, 5 chlorate of potash, 3 glue, 1$\frac{1}{2}$ red-lead, 12 water.

The Germans replace the chlorate either by nitrate of potash or nitrate of lead, together with red-lead, hence their matches strike silently, without the short detonation peculiar to English goods.

The match composition is coloured either with a coal-tar colour, ultramarine blue, Prussian blue, or vermilion. In preparing the composition, the glue and the nitre or chlorate of potash are dissolved in hot water, the phosphorus is then added, and carefully stirred in until intimately mixed, the whole being kept at a temperature of about 38° (100° F.). The fine sand and colouring matter are then added, and the mixture is complete.

Dipping-composition for safety-matches consists of 1 part by weight chlorate of potash, 2 glue, 1 sulphide of antimony, 12 water. For the rubber on the box, 2 parts of amorphous phosphorus and 1 of powdered glass are mixed with the solution of glue, and painted on the box.

Vestas are tipped with similar ingredients, but the taper being less rigid than wood, a larger proportion of phosphorus is added.

The heads of vesuvians are made up principally with powdered charcoal and saltpetre in some such proportions as those in the following:—18 parts saltpetre, 19 charcoal, 7 powdered glass, 5 or 6 gum arabic or gedder; to these, are added a little scent, in the form of satin-wood, lignum vitæ dust, cascarilla-bark, or gum benzoin, which render them fragrant when burning. The igniting-composition is identical with that for ordinary matches.

The production of matches is so enormous that it cannot be estimated, some idea of its magnitude may be gained from the fact that many large firms, such as Bell & Black, Hunt & Co., and Anthony Brisker & Co., of London, turn out daily upwards of 80,000,000, the first-named firm frequently producing this quantity of wax vestas alone per diem.

(See Explosives; Paraffin; Timber.) E. S.

MORDANTS (Fr., *Mordants*; Ger., *Beizen*).

In dyeing and tissue-printing, a very important part is played by "mordants." If we examine the action of colouring matters upon organic fibres and tissues, we find that they may be divided into two great classes. One group—the so-called substantive colours—are capable of attaching themselves at once to the article to be dyed, on simple immersion or steeping. Thus, if a piece of clean white silk or wool, or the human skin, be moistened with a solution of magenta, or, in fact, with the majority of the aniline colours, it is permanently dyed, and cannot be rendered white again by mere rinsing in water. The other group of tinctorial matters, which, till lately, at least, were by far the more numerous, have received the name of adjective colours. If yarn or cloth be steeped in solutions of these bodies, it may when taken out seem dyed; but on squeezing or wringing, and still more on washing in pure water, the colour is entirely removed, leaving the cloth merely somewhat soiled. It is true the distinction between these two classes is not absolute; many dyes which are substantive upon animal fibre prove merely adjective when applied to cotton or linen. Still, the classification, though not scientifically correct, is practically useful, and, as such, may be retained.

In order to cause the adjective colours to attach themselves to the fibre, so as to yield a full, thoroughly-dyed shade of a reasonable degree of permanence, recourse is had to the intervention of some third body, which is called a "mordant," and which enables the colour and the tissues to combine. Even in the case of substantive colours, mordants are very frequently called into requisition, because they brighten and modify the shade which would be obtained if the colour alone were employed.

One and the same colouring matter, if employed with different mordants, may give totally different shades—a fact which comes into great prominence in the so-called "madder-style" in calico-printing. If, for instance, there be printed upon different portions of a piece of calico: (1) strong acetate of alumina, (2) weak acetate of alumina, (3) strong acetate of iron, (4) weak acetate of iron, and (5) a mixture of the acetates of alumina and iron, and the cloth be then dyed in the madder beck, or, as is now the case, in a solution of artificial alizarine, there are produced: (1) full red, (2) pink, (3) black, (4) purple [violet], (5) chocolate. Other dyes can also be made to produce varied effects, according to the mordant selected, though not to such an extent.

The properties which a good mordant should possess are various. If for general use, it should not alter the colour of the fibre. This is the great advantage possessed by the compounds of alumina and tin; they leave the fibre white as they found it, and hence may be successfully used for all pure and bright shades, such as the prismatic colours. Other mordants, e. g. the preparations of iron, and certain chromium compounds, alter the colour of the fibre, or darken—technically called "saddening"—the colour of the dye. Thus cotton yarn, steeped in a solution of iron and exposed to the air, takes a rusty or buff shade; hence the preparations of iron cannot be employed for dyeing any colour with which such a ground would be incompatible. Iron, further, is a powerful saddening agent; in contact with tannin in its various forms, the dye-woods, cochineal, and the madder colours, it produces blacks, deep-olives, dark-browns, &c. Hence its use is necessarily very much restricted.

Mordants must, as a matter of course, be soluble, so that they may be presented to the fibre in a liquid state. Doubtless, many substances, when in a very fine state of suspension, are capable of combining with the fibre; but in this case, there is greater difficulty in producing perfectly even shades. It is, however, necessary that the mordants, or at least their essential constituents, should be easily rendered insoluble, as soon as they have combined with the fibre. Were this not the case, they could be washed away, and would prove useless.

Insolubility may be produced by various methods. Sometimes it depends on the escape of a volatile acid. Thus, if cotton yarn be mordanted with "red liquor" (acetate of alumina), and then hung up to dry, the acetic acid flies off, and the alumina is left behind upon the fibre, in an insoluble state, but still capable of combining with and retaining certain classes of colouring matters.

In other cases, the mordant, when brought into contact with the yarn or cloth, especially in presence of a large quantity of water, is decomposed. An oxide—perhaps under some circumstances an oxychloride, or a basic salt (sub-salt)—is deposited upon the fibre, whilst the bulk of the acid with which it was combined remains in the water. This takes place when yarns or cloths are worked in a solution of tin crystals, or in nitrate of iron.

Sometimes a new compound is formed; the colouring matter and the mordant, each soluble when taken singly, combine to form an insoluble compound, which is deposited in the pores of the material. This case occurs very frequently in wool dyeing, when the mordant and the colour are applied jointly to the fibre.

Lastly, insolubility may be produced by some special treatment. Thus, if a fibre is worked in stannate or aluminate of soda, and is then passed through a weak solution of sal ammoniac, the first-mentioned salts are decomposed, and the stannic acid (peroxide of tin) or alumina is left in an insoluble state in the fibre.

Hence, it may be concluded that, as far as the mineral mordants are concerned, they must be of an unstable constitution, held together by very feeble affinity, which may be easily overcome. In fact, many of the best mordants undergo spontaneous decomposition on keeping for a long time, on dilution with water, or on exposure to light. As a rule, the larger the proportion of acid to the base, the feebler is the mordant. If to a well-made tin spirit be added a proportion of free muriatic acid, the stability of the mixture is increased. The acid refuses to part with the oxide of tin, so the fibre is unable to counteract its opposition. As another instance, alum is not very efficacious as a mordant, because the sulphuric acid retains the alumina with a force which the fibre cannot readily overcome. But if a certain proportion of alkali be added, so as to combine with a part of the acid, the alum is converted into basic alum, which parts with its alumina more readily, and is a more efficacious mordant. Hence the so-called "balance" or proportion between the acid and the base is a point of the highest importance. If the base be in relative excess, and the mordant consequently too dead, the oxide will be precipitated rapidly and irregularly upon the fibre, and the shade produced will be cloudy, streaky, and dull. If the acid be in excess, the result is worse; the yarn or cloth is generally corroded ("tendered"), and the mordant is not deposited upon it in sufficient quantity. Hence the colour produced has a hungry, impoverished appearance. There is a very decided difference—which is not easily described—between a light colour fully dyed, and that which ought to have been a full shade, but has turned out meagre. Further, a mordant to be useful must have a decided affinity at once for the material and the dye, so as to enter into permanent union with both. On the other hand, this affinity may be too strong. If the mordant lays hold of the fibre too greedily, the shades produced will not be even. This is often the case in dyeing cochineal scarlets, unless the goods on being first entered into the dye-pan are turned very rapidly, so that the mordant may have less opportunity of attaching itself to one end of the piece of yarn in preference to the other. If, on the other hand, the affinity of the mordant for the dye be excessive, the colour produced, instead of being deposited on the fibre, is to a very considerable extent precipitated to the bottom of the dye-pan as a lake or pigment, whilst the goods are neither thoroughly nor permanently dyed. Such, for instance, is very generally the result if a solution of bismuth is used as a mordant along with any of the red woods. A fine, bright lake is produced, but the fibre is very imperfectly dyed. A combination between tissue, colour, and mordant should be effected regularly and slowly. If this point be not satisfactorily regulated, the shade produced will be flat, irregular, and loose, and will often smear off.

It must be remembered that mordants are not universal in their action; those adapted for wool are not suitable for vegetable fibres. As a general rule, the preparations employed for woollen and worsted goods are more acid than those which serve for dyeing cotton and linen; the latter require mordants of a very faintly acid, a neutral, or even an alkaline character, such as the aluminates and stannates. On the other hand, alkaline mordants can very rarely be used with safety upon wool. Preparations of lead, iron, and manganese play a very important part in cotton and linen dyeing, but they are of very little value for wool, where lead, indeed, is totally inadmissible. The nature of the colouring-matter to be employed is also an essential consideration. Tin has always had the preference for use in conjunction with cochineal, lac, and bright colours produced with the red woods, e. g. bar-wood reds, sapan pinks, &c., but it has given little satisfaction for madder reds, where the compounds of alumina have been found preferable. It has been proved that the acid employed in the composition of a mordant decidedly influences the colouring-matter, and must likewise be regulated in accordance with the fibre. It is known that a chloride of iron, or a nitrate of iron into the composition of which hydrochloric acid has entered, cannot be safely used for dyeing cotton warps of mixed goods, such as coburgs, delaines, merinos, &c. It delivers the iron, not only upon the cotton, but also upon the worsted. On the other hand, a pure nitrate or nitro-sulphate of iron will mordant the cotton fully, leaving the worsted or woollen warps untouched. Tin mordants which contain oxalic or tartaric acids are used for the brightest cochineal reds upon woollens and worsteds. If sulphuric acid is used instead of the oxalic or tartaric, as was done by Bancroft, the red is of a brown cast. Sulphate of tin produces a redder claret shade, if used upon woollens along with logwood, than does the muriate of tin under similar circumstances. These facts are of importance as regards the theory of the mineral mordants. It is generally supposed that hydrated alumina, hydrated oxide of tin, iron, &c., as the case may be, is deposited in the minute pores of the fibres in conjunction with the colouring matter, thus forming a lake. But in view of the facts just mentioned, showing the influence of the acids present, it must be presumed either that the substances precipitated upon the fibre retain a certain proportion of the acid in the state of a sub-salt (basic salt), or that the acids effect a permanent change in the properties of the colouring matter. It must be remembered that acids have a decided affinity for animal matter. If the finger-tips be plunged into sulphuric acid, and immediately afterwards washed in flowing water, the acid taste and the reaction with litmus paper will not be readily removed.

It is obvious that the theory of the action of mineral mordants, briefly given above, cannot be extended to the organic mordants. The action of albumen and its kindred substances in fixing many aniline colours upon vegetable fibres is totally different, and is best characterized by the common phrase, "animalizing cotton." Magenta, orchil, &c., are substantive colours upon wool, and, by coating cotton with albumen, it is furnished with a surface which is chemically identical with wool. The magenta is not combined with the cotton, but merely with a substance mechanically adhering to the cotton.

The most recent experiments decidedly refute the theory that dyes are fixed by the acid of a capillary tube in the centre of the fibre, into which the mordants and colours were supposed to penetrate. No such capillary tube exists, for example, in silk.

A brief description of the principal mordants and their application will now be given.

Alumina Mordants. — Alum, known also as rock-alum, roach-alum, is probably the most ancient and the most widely-used mordant. It is a double sulphate of potassium and aluminium (potash-alum), or of ammonium and aluminium (ammonia-alum). For most purposes, these two kinds differ little in value and utility, ammonia-alum containing a larger proportion of alumina, and dissolving more readily in water. These alums are not only used to a great extent as such, especially in wool dyeing, both alone and along with argol, chrome, &c., but also in the preparation of other aluminous compounds.

The most dangerous impurity which alum may contain is iron, a substance very injurious even in the minutest traces. To detect its presence, a portion of the sample dissolved in water is mixed with a few drops of solution of potassium ferrocyanide and ferricyanide (yellow and red prussiate of potash): an immediate blue precipitate shows the presence of iron. Or a little solution of tartaric acid is added to the solution, then an excess of pure caustic soda, and a drop of ammonium sulphide: a black coloration shows the presence of iron.

To distinguish ammonia-alum from potash-alum, add to the solution a little caustic soda, and apply heat. Ammonia-alum is at once known by giving off ammoniacal fumes, which may be recognized by the smell, by turning red litmus-paper blue, and by forming a white cloud with a rod moistened in hydrochloric acid; ammonia-alum, which, 20 years ago, was by far the more commonly met with, is now rare in the market. The Roman alum, which is now again coming into use, has a reddish cast, derived from the presence of a small quantity of oxide of iron, which, being in a condition insoluble in water and dilute acids, is perfectly harmless. It often contains a proportion of basic sulphate of alumina, and hence deposits its base, hydrate of alumina (aluminium hydroxide), more freely on the fibre. Basic alum is formed by adding ammonia or potash-lye, as the case may be, till the precipitate formed begins to appear permanent on shaking.

Cubic alum is obtained in a very similar manner, by dissolving alum in boiling water, and adding slaked lime in the proportion of $\frac{1}{12}$ the weight of the alum. It forms cubic crystals. Potash, soda, or their carbonates, if cautiously added to solutions of alum, withdraw a part of the acid, and form a salt which has a greater affinity for the fibre.

Sulphate of alumina, known also as cake alum, patent alum, or concentrated alum (aluminium persulphate), differs from alum in not containing an alkaline sulphate. It contains much more actual alumina—the really active principle—than either potash or ammonia-alum, and is much more readily soluble in water. Hence it goes farther, and is more convenient in use. Its disadvantages are—not being a crystalline compound, its composition is not absolutely invariable, traces of free acid being not unfrequently present; sometimes also it contains iron to a serious extent. It must be remembered that great improvements have been effected in the preparation of this salt, and it will doubtless be ultimately obtained free from iron and from uncombined acid. When this end is accomplished, alum will have no further claim on the dyer. Sulphate of alumina may be rendered basic in the same manner as potash- and ammonia-alum.

Next in importance to alum, comes red liquor, acetate of alumina, or aluminium acetate, a compound very largely used in cotton-dyeing and -printing; more rarely with animal fibres. It is prepared in two general methods. A solution of alum, or of sulphate of alumina, is mixed with a suitable proportion of lead acetate (sugar of lead) or of acetate of lime. Sulphate of lead (or of lime) is precipitated, and the clear liquid is the acetate of alumina required. Various prescriptions for this mordant will be found in the article on Calico-printing. It may be noted that small variations in the quantities of the ingredients often make an important difference in the results. Carbonate of soda crystals are generally employed to give a more basic product, and many practical men hold that a red liquid prepared from alum is often preferable to one produced from sulphate of alumina, the acetate of potash or of ammonia present in the former case playing a certain part in the production of the colour.

Red liquor may also be obtained by dissolving precipitated hydrate of alumina in the strongest acetic acid, until the latter is completely saturated.

In whatever manner acetate of alumina is prepared, the absence of iron is essential. Red liquor cannot be indefinitely preserved, especially if freely exposed to the air, as the acid gradually escapes, and the composition of the mordant is consequently altered.

Nitrate of alumina (aluminium nitrate) is not extensively used. It is prepared when needed by mixing together, in equivalent proportions, solutions of alum or sulphate of alumina, and nitrate of lead. Sulphate of lead is deposited, and the clear liquid is nitrate of alumina.

Muriate of alumina (aqueous aluminium chloride) is also rarely used. It is prepared by dissolving hydrated alumina in hydrochloric acid, by decomposing a solution of the sulphate of alumina with one of chloride of calcium, or more economically under Fournier's patent, by mixing solutions of sulphate of alumina and common salt, and exposing the mixture to a temperature of – 2° to 0° (28½°–32° F.). Sulphate of soda is deposited in fine crystals, whilst hydrochlorate of alumina remains in solution.

Hyposulphite of alumina (aluminium thiosulphite) has been proposed by Kopp as a substitute for red liquor. It is readily obtained on decomposing sulphate of alumina by hyposulphite of lime. By the action of sulphurous acid gas upon a mixture of the tank-waste from the soda manufacture, with 10 per cent. of its weight of sulphur and water, previously boiled together, hyposulphite of lime is obtained in fine crystals. Kopp considers that it possesses distinct advantages over red liquor; but in England, the opinion of practical men is not in its favour.

Oxalate of alumina has been made by dissolving precipitated alumina in oxalic acid, but is rarely used.

The aluminate of soda (alkaline pink mordant) forms an exception to the rest of the aluminous mordants, as it consists of alumina dissolved not in an acid, but in an alkali. It was originally prepared by precipitating alumina from alum or from sulphate of alumina by means of caustic soda, and adding the latter in excess, with the aid of heat, till the precipitate was redissolved. It is now to be met with in the solid state, and nearly pure.

In dyeing, it produces every effect yielded by alum, and, in addition, certain results which cannot be otherwise obtained. Notwithstanding its alkaline nature, it may be used to fix colours upon wool. In calico-printing, it serves as a pink mordant, the pieces being afterwards taken through a bath of sal ammoniac, or chloride of zinc.

Antimony Mordants.—Compounds of antimony play but a limited part as mordants. An American authority recommends the "oxymuriate" of antimony—which may perhaps mean antimony terchloride, or antimonic acid dissolved in hydrochloric acid—as a mordant for dyeing a scarlet shade on cotton with Sehlbach's "extra-scarlet," a coal-tar colour.

Muriate of antimony (antimony terchloride), has been used along with oxalic acid for dyeing grain and lac scarlet on woollens. The result is harsh and chalky. Antimonial compounds have been used as a "prepare" for steam colours in printing, but without advantage.

Antimony tartrate and tartar emetic (antimony potassium tartrate) are now used to some extent along with tannin in fixing certain aniline colours upon cotton.

Arsenic Mordants.—Arseniate of soda along with red liquor is used to a large extent in fastening aniline and other coal-tar colours upon cotton tissues. The discovery of an available substitute for so dangerous an article is very desirable, especially in the present excited state of public feeling with regard to poisonous colours.

Bismuth Mordants.—Bismuth is too expensive, and though capable of yielding rich lakes, its affinity for textile fibres is feeble, and the colours dyed and printed with its solutions, e. g. the aceto-nitrate, are loose and uneven.

Chromium Mordants.—Several compounds of chromium are largely used in dyeing and printing. The sesquioxide of chrome dissolved in acids, such as sulphuric, nitric, or acetic, has a considerable affinity for textile fibres, and also for certain colouring matters; but as it gives a pale greenish colour, it is at once excluded in the case of most light and bright colours, to which an admixture of green would be fatal. The aceto-nitrate of chrome is prepared by G. Witz as follows:—Into a large stoneware pan, holding 20 gal., are poured 6 gal. boiling water, 47¼ lb. nitric acid at 62° Tw., and 6 lb. 9 oz. bichromate potash in very coarse powder. The following mixture is then poured in, by about 17 fl. oz. at a time, stirring with a large glass rod, and allowing the frothing each time to subside before adding a fresh lot:—3¾ lb. white glycerine at 44° Tw., and 90¼ lb. acetic acid at 25¼° Tw. Whilst adding the first half of this mixture, it is needful to proceed slowly, but afterwards it is added more briskly, to keep up the reaction. This process is performed in the open air. When all is dissolved, the liquid is passed into a copper pan fitted with a steam-jacket, heated quickly to a boil, and kept at that point for two minutes, or until a shallow layer of the liquid takes a fine green. It is then poured back into the stone vessel, and allowed to cool overnight. The liquid is next poured off, and the crystals of saltpetre are washed with 4 lb. cold water; the liquid is decanted off, and mixed with the former, so as to form 2 gal. mordant at about 57½ Tw. This mordant may be used for alizarine pieces, for cœruleine shades along with bisulphite of potash, for logwood blacks, and for "Havraneck green," along with prussiate of potash, &c.

Chrome-alum is a double sulphate of chrome and potash. It contains no alumina and no chromic acid, and cannot be prepared, as some dyers erroneously imagine, by mixing bichromate of potash and ordinary alum. It is chiefly obtained as a residual product, e. g. in the conversion of anthracene into anthraquinone, in the manufacture of artificial alizarine, and is recommended by Dr. Reimann for dyeing logwood blacks, especially in conjunction with iron-alum. (See Iron Mordants.)

The chromium-compounds most widely used in dyeing are the combinations of chromic acid with an alkaline base, generally potash. The yellow or neutral salt (potassium chromate, not to be confounded with chrome yellow, a lead chromate) would be very useful, if it could be obtained in an unvarying state. It is generally found contaminated with various proportions of carbonate of potash, and containing more or less moisture. Those who wish to witness its interesting behaviour with many organic colouring matters may avoid this difficulty by using 151 parts of the bichromate and 143 parts of clear soda crystals not effloresced. The yellow chromate is much more widely used on the Continent than in England.

The bichromate of potash (potassium dichromate), and often known as red chromate, bichrome, red chrome, or simply chrome, is used to a very large extent in dyeing blacks upon wool, in conjunction with logwood. Along with fustic, red woods, orchil, &c., with or without logwood, it yields browns, yellows, bottle-greens, dark-greens, olives, purples, and intermediate shades. All these colours are cheap, requiring little time or labour, and are very fairly fast.

Copper Mordants.—Compounds of copper, though used in dyeing and printing to some extent, serve rather as oxidizing agents or alterants, than for fixing colours upon the fibre. The principal are:—

Ammoniuret of copper is formed by adding liquid ammonia in excess to a solution of sulphate of copper, till the precipitate is redissolved, and a beautiful violet-blue liquid is produced. When diluted, it is sometimes used for giving a pale-green upon vegetable tissues by padding, dyeing, and rinsing.

Chloride (muriate) of copper is most used on the Continent in printing. In England, nitrate or sulphate of copper is used in its place, along with sal ammoniac. It may be easily prepared, if desired, by mixing solutions of sulphate of copper and chloride of calcium, drawing off the clear liquid for use.

Nitrate of copper is generally obtained as a residual product in cleaning articles of copper and its alloys. The nitrate is sold as a deep-blue liquid at about 90° Tw., and is often very impure, containing zinc, iron, &c., not intentionally, but from carelessness. It is chiefly used as an oxidizing agent in printing, e. g. in catechu browns.

Sulphate of copper, known also as blue vitriol, blue-stone, and Roman vitriol, is generally prepared directly from copper ore. It is used by printers as a resist, and by dyers as a mordant, generally in conjunction with copperas, alum, argol, &c. Sulphate of copper sometimes contains more than 60 per cent. of sulphate of iron. Such mixtures are frequently known by the names of Salzburg vitriol, Cyprus vitriol, admont vitriol, and eagle vitriol. They are to be condemned. If the dyer requires the joint action of blue-stone and copperas, he had better have both these substances in a pure state, and mix them himself in known proportions.

Verdigris (acetate of copper) is now comparatively little used. It is employed in catechu colours, in resists for indigo-styles, and as an oxidizer in some steam colours. In dyeing blacks on silks, and logwood blues on wools, it is also used. An old Act of Parliament (George III., 20) imposes a penalty of 20*l.* for every piece of woollen cloth dyed a logwood blue in this manner. This curious statute is said to be still unrepealed.

Iron Mordants.—These are both numerous and important.

Copperas (green vitriol), scientifically known as ferrous sulphate, may be made by dissolving scrap iron in dilute sulphuric acid. Practically it is obtained by exposing the soft whitish iron pyrites of the Coal-measures, often known as "brass-lumps" or "coal-brasses," to the action of air and moisture. The water being decomposed, the hydrogen escapes, and the sulphur and iron are both oxidized. The solution thus obtained is concentrated, when it deposits copperas in pale greenish-blue semi-transparent crystals, containing 45 per cent. of water, which, on exposure to a gentle heat, escapes, leaving a white powder. Copperas should be hard, clear, and dry. If soft, and of a whitish or greyish-green colour, sulphate of alumina is probably present—the most objectionable impurity—which is often met with if the pyrites have not been duly selected, or if the crystallization has been carried on at too high a point of concentration. To detect the presence of alumina, a little of the sample is dissolved in water, heated with some pure nitric acid to peroxidize the iron, and the solution, after being heated till all the free nitric acid has been expelled, is mixed with a considerable excess of pure caustic soda. The mixture is heated in a clean iron vessel, diluted with water, filtered, and a solution of sal ammoniac is added to the clear liquid. If the copperas contains alumina, a white precipitate will be formed.

Old copperas, especially if it has been exposed to moist air, turns brown—a feature preferred by some consumers, though only valuable as a sign that the crystals do not contain any sulphuric acid. This brown appearance is therefore imitated by scattering lime-dust over the heaps, or watering them with stale urine.

"Calcined copperas" is an article for which some dyers have a peculiar liking. It is prepared by heating ordinary raw copperas. If merely the water of crystallization is given off, the copperas remains soluble, and is, weight for weight, stronger than in its original state. If actually calcined, it becomes to a greater or less extent insoluble, and is therefore, *pro tanto*, wasted.

Copperas is now very extensively used in the manufacture of so-called nitrate of iron, and sometimes of acetate of iron. As a mordant, it is less employed than formerly.

Persulphate of iron, otherwise known as red sulphate (ferric sulphate), is not produced in the form of crystals. It may be made by dissolving copperas in water, applying heat, and gradually adding nitric acid in small proportions, till a little of the liquid no longer gives a blue precipitate with potassium ferricyanide (red prussiate of potash). Or native hydrated ferric oxide is boiled in oil of vitriol. Persulphate of iron is little used under its own name, but much of the nitrate of iron, commonly so called, is little else than persulphate.

Iron-alum is much used abroad, and is recommended by Dr. Reimann in conjunction with chrome-alum when dyeing logwood blacks. It may be obtained as follows:—78 parts of the red oxide of iron are dissolved in 147 parts of oil of vitriol with the aid of heat. The solution is then diluted with water, and mixed with 87 parts sulphate of potash. The solution is next allowed to crystallize. These crystals, being absolutely unvarying in composition, are free from many of the objections made to the nitrates and the persulphate.

Muriate of iron (solution of ferrous chloride) is prepared by dissolving waste iron in hydrochloric acid of the common commercial strength (32°–34° Tw.) till the solution reaches 80°–85° Tw. It requires to be kept from contact with the air. It is sometimes used in producing catechu drabs and slates.

Permuriate of iron (solution of ferric chloride) is made by dissolving scrap iron in a mixture of nitric and hydrochloric acids. It is used still less than the muriate.

Nitrate of iron is a name given to a whole group of mordants, differing widely in their nature, manufacture, and applications. Some of these compounds contain no acid except nitric, others are made with a mixture of nitric and sulphuric. and in others, again, acetic acid is present in addition. In general, the iron is entirely in the ferric or most highly oxidized state; whilst in others, there is more or less of the proto or ferrous salt. Some nitrates of iron are made from copperas, others from scrap-iron, and others of a mixture of both. In sp. gr., they range from 40° to 120° Tw. However they may differ in other respects, it is important that they contain no hydrochloric acid, nor any chloride. If such is present, the iron will be less readily deposited upon the fibre, and—a greater evil—in dyeing mixed goods, it will work upon the woollen or worsted in preference to the cotton. Another very important point is that the acid and the base should be accurately proportioned, or, as it is technically termed, "balanced." If there is an excess of acid, the fibre will not be able to take up a sufficient quantity of the base, whence the shades produced will be meagre. The tissue itself, and in case of printing, the rollers and doctors, will be corroded. If, on the other hand, the proportion of iron is relatively too great, much of the colour will be deposited not on the fibres, but at the bottom of the dye-beck, and the shades obtained will be dull, irregular, and deficient in fastness. This balance between the acid and the base varies, however, according to the purpose for which the nitrate of iron is prepared.

A "black-iron," i. e. for dyeing and printing black upon cotton yarns, pieces, or the cotton warps of mixed goods, should be very thoroughly neutralized, or, as it is termed, "killed." Still, even here, if the oxide of iron is deposited too rapidly and irregularly to combine with the organic colouring matter, the goods will not only appear cloudy or streaky, but may even display buff patches. For this purpose, a nitrate of iron—or rather a nitro-sulphate—made from copperas is preferable to one from the metal. It is not necessary that the whole of the iron should be peroxidized. A mordant containing a mixture of proto- and per-salt (ferrous and ferric nitro-persulphate) yields fuller and richer blacks; the former of these compounds, if used alone, giving a bluish, and the latter a brownish cast. The following process will yield a good black-iron. Take a large, strong cask, holding about 140 gal.; remove one end, and put into it 5 cwt. of dry, clean copperas, free from alumina and from both fine powder and very large lumps. Upon it, pour 120 lb. of nitric acid at

64° Tw. (the so-called double aquafortis of commerce), and stir the whole up together with a long pole, so that every part of the copperas may come into contact with the acid. In the stirring, there is a certain art. A violent revolving movement must be avoided; the copperas should be turned over from the very bottom, working as if trying to find some lost article with the end of the pole. As the fumes given off are absolutely suffocating, the cask should be placed in a shed with open sides, so that the workmen may stand on the windward side. In case of inhaling these fumes, relief is obtained by drinking very strong vinegar, or acetic acid diluted with water. On no account should whisky or rum be used. In the evening, the cask is stirred up again. This process is repeated on the second day at morning and evening, and again on the morning of the third day. At night the reaction will be over, and if the operation has been well conducted, the copperas will have been entirely dissolved, or a very small quantity may be left in the cask. Water is then poured in, until the whole, after being thoroughly stirred up, marks about 75°–80° Tw. The liquid is allowed to settle, and is run off into carboys, which should stand in a dark place, exposed neither to heat nor cold.

Some manufacturers modify their "black-irons" by adding a solution of brown sugar of lead, in proportions below 95 lb. to 138 lb. of the copperas originally employed. In consequence, the lead precipitates its equivalent of the sulphuric acid present, its place being taken by the acetic acid previously present in the sugar of lead. If any free nitric acid exist, it will combine with some of the iron, formerly held by the sulphuric acid; whilst a corresponding proportion of acetic acid will be set free. A black-iron thus corrected will neither injure tissues, colours, nor printing machinery. Hence it may safely be used for burl or burr dyeing.

When woollen pieces have been dyed, they are often found more or less spotted over with small grey specks, upon which the dye, as mixed for woollens, has not taken effect. These are due to small portions of vegetable matter, which have become entangled in the wool. To render the piece of a uniform black, it must therefore undergo a second process, which is, in fact, cotton-dyeing. For this purpose, the "burling" iron is required, and the nitrate of iron must be very accurately prepared. If too acid, it may discharge or modify the colour of the wool; and if too dead, it may occasion rust-smears.

"Common iron" is used for "saddening," as it is called, such colours as olives, dark-browns, drabs, &c. It is sharper than black-iron, and is a perfect per-salt (ferric salt).

It may be obtained by the process just recommended for black-iron, using 130–135 lb. of nitric acid to 5 cwt. of copperas. If any copperas remains in the cask unattacked, the liquid is drawn off before diluting with water.

A saddening-iron for drabs is often made as follows:—Ordinary nitric acid is let down to 34° Tw., and of this, 100 lb. are placed in a large stoneware pan. In it, are dissolved, firstly, 4 lb. of clean scrap-iron, and afterwards, as much copperas is gradually added as the acid will take up, which is generally about ¾ cwt. It is finally set at 60° Tw. with water.

So-called "blue-irons" were formerly very much used for dyeing Prussian blues upon cotton yarns, and upon the cotton warps of mixed piece-goods where the weft had been dyed with an aniline blue, and in producing a blue base for greens. These uses are now of very much less importance, since the discovery of coal-tar colours, which work well upon vegetable fibre.

Blue-irons are sharper than black and common irons, as their acidity is to a great extent neutralized by the prussiate of potash. A blue-iron for cotton yarn and unmixed cotton piece-goods may be made by the first process for a common iron, viz. 5 cwt. copperas to 130 lb. nitric acid.

For light-blues on the warps of coburgs, delaines, &c., double aquafortis (nitric acid) is let down to 32° Tw., and clean scrap iron is dissolved in it as long as there is a good action, and reddish fumes are thrown off. It should mark 42°–43° Tw.

For darker blues, verging towards a violet, put 24 lb. nitrate of soda, freed from common salt, into 15 gal. water, and stir till dissolved. Then add by degrees 20 lb. of oil of vitrol, feeding with scrap iron as required. The heat must not be allowed to get very high. In cold weather, both the oil of vitriol and the iron are added more rapidly than in summer. This nitrate of iron contains sulphate of soda, and, if kept for any length of time, deposits a sediment.

Analytical processes are of little avail in finding the practical value of an "iron," since the quality of any sample depends not merely upon the proportions of the ingredients, but upon the manner in which they are combined.

Pyrolignite of iron, likewise called acetate of iron, black-liquor, and iron-liquor, is less used in dyeing than in calico-printing, where it plays a great part, especially in the madder-style. It is generally prepared on a large scale at wood-vinegar works. Scrap-iron is submitted to the action of raw acetic (pyroligneous) acid in a series of vats, till thorough saturation is obtained. It has been perfectly well ascertained that the purified acid, free from tarry matters, gives a much less satisfactory product. These impurities retard the conversion of the iron into a salt of the peroxide (ferric salt), in which state its efficiency is much lessened. Black-liquor is also sometimes prepared by the consumer by a process of double decomposition.

A solution of copperas is mixed with one of brown sugar of lead, or crude acetate of lime, and after settling, the clear liquid is drawn off for use. (For particulars concerning both these processes, see p. 31.)

The specific gravity of black-liquor, as met with in commerce, ranges from 30° down to about 10° Tw. Its properties are very considerably modified by the degree of strength at which it is used. At 6° Tw., it gives with madder a full and fast black. If diluted down to 4° Tw., or lower, it yields with madder and artificial madder colours various shades of purple and lilac. These colours are called by Continental writers violets. The words *purpur* (German) and *poupre* (French) are applied to shades between crimsons and reddish-violets. Artists in England use the word "purple" in the same sense, and not as synonymous with "violet." Used in combination with red-liquor in different proportions, it gives shades of chocolate.

Along with black-liquor, may be mentioned a proposed substitute, which possibly deserves more attention than it has yet received—hyposulphite of iron. It may be prepared by mixing a solution of copperas with crystals of hyposulphite of soda, or by decomposing copperas with hyposulphite of lime. According to Kopp, the fixation of the base of this mordant upon the fibre is very slow and very intimate, and the tissues are not in the least injured. Other authorities, among them C. O'Neill, maintain that the action of the hyposulphite is irregular, and that the colours produced are consequently uneven.

It has been proposed by Persoz to dissolve pyrophosphate of iron in ammonia. The solution, if printed on cotton, and dried very slowly, gives, when dyed with the madder-colours, exceedingly pure purples and lilacs. It is said that cloth thus mordanted can be successfully dyed in becks which no longer give any colour on cotton prepared with black-liquor.

LEAD MORDANTS.—Four compounds of lead, the acetate, nitrate, and sulphate, and the plumbate of soda, are used in dyeing and printing. The affinity of oxide of lead for the fibre is feeble, and though it combines very readily with organic colouring matters, the resulting compounds—lakes—are wanting in depth of colour and beauty. Hence salts of lead are but rarely used as true mordants, i. e. for fixing animal, vegetable, or artificial colours upon tissues. Another defect of lead is that it is very readily blackened by sulphuretted hydrogen, &c., or if brought into contact with organic matter containing sulphur, such as wool. The nitrate of lead was used in fixing murexide purple, a colour now, we believe, no longer in the market. The acetate—sugar of lead—and the basic acetate, otherwise known as subacetate of lead, Goulard's extract, or lead vinegar, have been used with some success in dyeing and printing aniline colours upon cotton. The cloth is alternately padded in the lead solution, and in weak ammonia, or is soaped, and then mordanted with lead.

The chief use of all the lead compounds is the production of yellow and orange colours upon cotton in conjunction with bichromate of potash, a style of work much in vogue in printing.

MANGANESE MORDANTS.—Manganese has a very powerful affinity for organic matter. Cotton steeped in the permanganate of potash soon takes a deep-brown colour. The same effect is produced if the cotton is worked in a solution, as nearly neutral as possible, of sulphate, chloride, or acetate of manganese, and is then taken through a weak bath of chloride of lime. The colour thus obtained upon the fibre is too dark to admit of this process being used for fixing any organic dye. But the hydrated protoxide of manganese is white, or of a very faint pink tint, and hence, to use manganese successfully as a mordant, it is merely needful to pass the tissue, after being worked in permanganate of potash, into a solution of some powerful reducing agent, preferably a solution of tin-crystals. By this means, a deposit of white protoxide is left upon the fibre, and may serve as a mordant.

SILICA AS A MORDANT.—Silica in the amorphous, and still more in the hydrated, state, has a decided affinity for organic colours—a circumstance which approximates it to alumina. This property may be practically utilized in the following manner. The tissue is worked in a solution of silicate of soda—so-called soluble glass—and is then taken through a dilute acid, such as sulphuric, or hydrochloric at about 1°–1½° Tw., or through a solution of sal ammoniac.

The silicate of soda is thus decomposed, and hydrated silica is deposited upon the fibre. If the goods are then worked in a solution of a colouring matter, they become thoroughly and permanently dyed. This process has chiefly been used for the fixation of certain aniline dyes upon cotton. It is less applicable upon silk and wool, to which, moreover, the same colours adhere in general without the intervention of a mordant.

SULPHUR AS A MORDANT.—Hyposulphite of soda was proposed some time ago for fixing certain aniline greens, and was used with success. The suggestion was due to a photographer, who, having been accustomed to employ hyposulphite of soda as a fixing agent in his own department, concluded that it would "fix anything." This case is interesting as an example of practical success reached by a false theory. There are many such.

It has since been found that the value of hyposulphite of soda depends on the fact that tissues saturated therewith, and afterwards taken through an acid, or even exposed to the air, become coated with finely divided sulphur, which, in this state, absorbs colours by surface attraction, very similarly to amorphous silica. Sulphur in this condition is a useful mordant for many coal-tar colours, but is of little value for the fixation of eosine.

Tin Mordants.—Till within the last twenty years, tin mordants might, perhaps, claim the supremacy over all others, since the brightest and most beautiful colours, whether upon cotton, silk, or wool, were fixed by their means. Their importance is now diminished, inasmuch as many of the finest shades formerly obtained from natural colouring matters with their intervention are obtained in even greater purity and brightness from the aniline colours. Still the applications of tin in dyeing and tissue-printing remain extensive and manifold. To enumerate and describe all the tin compounds which have been, and still are, in use, would require a volume of fair size. They comprise both stannous and stannic salts, or, as they are still technically named, protomuriate, protosulphate, &c., and on the other hand, permuriate, nitromuriate, or oxymuriate. Lastly, in the stannate of soda, the tin appears not as a base, but as an acid. The affinities of tin, both for the fibre and for the colours, are strong, and the "lakes" which it forms with the latter are rich and bright. Though not exempt from the action of sulphur, it blackens much less rapidly than lead.

The so-called protochloride of tin, protomuriate, or simply muriate (stannous chloride), is made by allowing hydrochloric acid at about 32° Tw. to act upon granulated or feathered tin, with the aid of heat. The process is generally conducted in large stoneware vessels heated by hot water or steam. In some establishments, hydrochloric acid gas, just as evolved by the action of sulphuric acid upon common salt, is allowed to pass over granulated tin in stoneware cylinders, down which water is constantly allowed to trickle. Muriate of tin is sold in three states, differing merely in concentration.

Single muriate is a solution ranging in strength from 40° to 60° Tw., and containing from 1 to 2 oz. metallic tin in the lb. It is used by woollen dyers. Double muriate of tin varies in strength from 70° to 120° Tw., and contains proportions of tin from 2½ to 5 oz. a lb. The weaker and more acid kinds are used in woollen-dyeing; and the more neutral and thoroughly saturated kinds, from 110° to 120° Tw., for cottons. The mere specific gravity, however, gives no certain clue to the composition of a sample, as, even in the absence of all impurities, a variety in proportion may occur. Some makers dissolve the tin in undiluted acid at 32° Tw., whilst others add water before dissolving. The higher the original specific gravity of the acid taken, the smaller will be the proportion of tin needed to bring it up to any given degree of the hydrometer. The chief impurities which may be met with are sulphuric acid and sulphates of zinc and magnesia.

Tin crystals, sometimes called salts of tin, are merely muriate of tin evaporated to crystallization. They should contain about 52 per cent. of metallic tin. A good sample dissolves in about ten times its weight of water, with little or no turbidity. If a few drops of pure hydrochloric acid are added to this solution, no precipitate should be formed on dropping in a solution of barium chloride. Should a white precipitate appear, sulphuric acid in some combination is present.

The ordinary hydrochloric acid used for dissolving tin generally contains a little sulphuric acid, but the quantity is too small to produce more than a faint white turbidity in the solution of the tin crystals.

To determine the actual proportion of tin present in a sample of tin crystals, or of the liquid muriates, the following volumetric process may be used. A standard solution of tin is first made up by dissolving 500 gr. of pure tin (grain-bar) in pure hydrochloric acid, an operation which may be facilitated by putting it into contact with a platinum crucible. The liquid is then made up with distilled water to exactly 10,000 grain-measures. Every 20 grain-measures of the solution will contain consequently 1 gr. of tin.

A standard solution of iodine is then prepared by weighing out 127 gr. of pure iodine and 180 gr. of pure potassium iodide. They are then dissolved in 10,000 grain-measures of water, without applying heat, and the solution is preserved in 6-oz. stoppered bottles.

To find the value of this iodine solution, 100 grain-measures of the standard tin-liquor, containing of course 5 gr. of tin, are measured off into a beaker, and mixed with bicarbonate of soda in excess, and with sufficient double tartrate of potash and soda to keep the liquid from precipitating. A little weak starch paste is then added, and the iodine-solution is dropped in from a burette, till a faint but permanent blue tinge is seen in the glass. The number of degrees on the burette consumed show how many grain-measures of the iodine solution represent 1 gr. of metallic tin.

For the actual test of the crystals, a known quantity is weighed out, put into a beaker, and dissolved in distilled water, with the aid of a drop or two of hydrochloric acid, so as to give a perfectly clear solution. Bicarbonate of soda and double tartrate of potash and soda are added as before. The starch-paste is then added, and the iodine solution is dropped in as before, till the blue colour appears. From the number of grain-measures consumed, as shown on the burette, the percentage of tin in the crystals is readily calculated.

Next come what may be called mixtures of muriate of tin with other acids, their properties being thus modified. The following are specimens in extensive use :—

Amaranth Spirit.—Mix 95 lb. hydrochloric acid at 32° Tw. with 5 lb. oil of vitriol, and dissolve in it 4 lb. 11 oz. of tin. Used for dyeing reddish-violet with the woods on woollens and worsteds.

Yellow and Orange Spirit.—Take 5 lb. 11 oz. of double muriate at 80° Tw., mix separately 2 lb. oil of vitriol and 2 lb. water, and when cold, stir it into the double muriate. The more tin there is in the double muriate, the more the cloth will show a greenish reflection, if held up to the light and looked at along the surface. For woollens or worsteds.

Scarlet Finishing Spirit.—Take 3 pints muriate of tin at 54° Tw., and 2 oz. oxalic acid. Dissolve, before mixing, in hot water enough to set the whole at 40° Tw. Used for finishing grain scarlets which have been grounded with nitrate of tin. Some dyers prefer to substitute tartaric acid for a part, or even for the whole, of the oxalic acid. In soft woollen goods, the strength of the muriate of tin may be raised to advantage at 70°–80° Tw. A spirit thus prepared acts well for cochineal orange, maize, &c.

On the Continent, nitro-muriate of tin (see below), is generally used for dyeing cochineal and lac scarlets, &c., on woollens.

Plum Spirit.—Take 2 gal. muriate of tin at 70° Tw. In another vessel, mix sulphuric acid and water till the mixture stands at 28° Tw. when cold. Add of this 1 gal., and stir well. This mordant is used for dyeing plums, reddish-violets, and brownish-purples on wool.

Oxalate of Tin.—In the strict sense of the words, this is not a commercial article, but the name, generally shortened into "Ox. Tin," is given to mixtures of muriate of tin with sulphuric and oxalic acids in different proportions. The following, which is largely in use, may serve as an example:—

Muriate of tin at 80° Tw., 6 gal.; sulphuric acid at 42° Tw., 3 gal.; oxalic acid, 2 oz. a gal. These spirits are used for finishing royal blues, topping blacks, where "bloomy" reflection is required, and as a scarlet or orange spirit with cochineal, lac, flavine, young fustic, &c.

Some compounds of tin are used in dyeing which probably contain an oxide intermediate between stannous and stannic. These solutions are of a rich deep-amber colour, and in warm weather keep very badly. Of these mordants, the most important is nitrate of tin, scarlet spirit (or bowl spirit), much used in Yorkshire and in Scotland for grounding cochineal colours on woollens and worsteds.

To prepare this spirit, a quantity of so-called "single," or "dyers'" aquafortis, i. e. nitric acid at about 32° Tw., containing a quantity of hydrochloric acid, or of an alkaline chloride, and totally free from sulphuric acid, and from the lower oxides of nitrogen, is placed in a large clean stoneware bowl. The finest quality of grain-bar tin, not feathered, is then dissolved in it, in the proportion of 1 lb. to every 8 lb. of the acid. Certain niceties in working are essential to success. If the acid is average in quality, and the weather is temperate, some 4–5 rods are laid in the bowl, and allowed to dissolve quietly, without stirring, or the application of heat. After a time, the liquid "turns," i. e. assumes a deep-amber or light-orange colour. When this has occurred, all difficulty is over, and nothing is needed but to add the rest of the tin by degrees, taking care that the reaction neither dies down nor grows violent. There must be no effervescence, nor production of orange-coloured bubbles or fumes. If the process fails, the change of colour does not occur, and the liquid, after remaining colourless for some hours, suddenly turns thick and turbid. If too much tin has been introduced at first, orange fumes rise up, and the tin is deposited in an insoluble state, and is useless. In winter, 8–10 rods may be put in at the beginning, without danger. In hot weather, two or even one is sufficient, and, if convenient, the bowl may be cooled by placing it in a stream of cold water. If the temperature is very high, the spirit may be started by putting into the bowl half a handful of dry, clean, granulated tin. Nitrate of tin, if well made, marks 58°–60° Tw., and contains 2¼ oz. tin per lb.

Purple Spirit, for producing wood purples and violets upon wools and worsteds, is made as follows:—Fresh, well-made nitrate of tin is gently warmed by setting the bowl in a larger vessel of hot water, and is allowed to dissolve as much grain-bar tin, in the rod, as it can take up. It marks about 80° Tw., and should be used immediately.

Aniline Spirit, so-called, is used for fixing aniline colours upon the cotton warps of delaines, &c., and for producing some very rich shades with dye-woods. It is prepared from 5 lb. single aquafortis at 32° Tw., 2½ gal. hydrochloric acid at the same strength, and 12 lb. grain-bar tin in the rod. The acids are mixed in a bowl with upright sides. About 12 rods are put in at first, arranged at equal distances round the side of the bowl. More tin is added as these dissolve, but the temperature must not become excessive. The finished spirit is of a reddish-amber colour, and contains about 20 oz. of tin per lb.

Many recipes, in which tin is directed to be dissolved in different proportions of nitric acid, with the addition of sal ammoniac, will yield a mordant similar in properties to the above.

The stannic salts or per-salts of tin are prepared by two very different processes; (1) A pure aqueous stannic chloride, otherwise called perchloride of tin, bichloride of tin, stannic hydrochlorate, dyers' composition, and sometimes scarlet spirits, may be obtained by saturating double muriate of tin at the highest strength, with chlorine gas till a small portion, taken out and dissolved in water, no longer gives a black precipitate with a solution of mercuric chloride (corrosive sublimate). The solution, with or without the addition of tartaric or oxalic acids, may be used for dyeing cochineal and lac scarlets upon wool. Or (2) tin crystals are dissolved in hydrochloric acid, heat is applied, and nitric acid is added in small proportions at a time, avoiding excess, till the above-mentioned black precipitate is no longer obtained. Or the metal is dissolved in mixtures of nitric and hydrochloric acids. Whenever nitric acid is used, it is never entirely driven off, and the resulting product differs in its action upon colours from that obtained by other processes. Hence it is improbable that pure tin composition would give all the results obtained with these mixtures. The following prescriptions may serve as specimens :—

Red cotton spirit, known also as crimson spirit, is made by mixing 6 gal. hydrochloric acid at 32°–34° Tw., 1 gal. nitric acid at 64° Tw., and 1 gal. water. After standing for a short time, enter by degrees 6 lb. of tin in the rod, beginning with 6 rods more or less, according to the weather, and adding the rest by degrees. The mixture must never get very hot, so as to give off orange vapours, nor must it ever be stirred. In 8–9 hours the whole of the tin will be dissolved, and the liquid will be of a clear pale straw-colour. Another red cotton spirit is made with 8½ gal. hydrochloric acid at 35° Tw., 1½ gal. nitric acid at 64° Tw., 1 oz. bichromate of potash, and sufficient tin to bring up the sp. gr. of the solution to 54° Tw.

Barwood spirit is made with 5 gal. hydrochloric acid at 32° Tw., 1 gal. nitric acid at 64° Tw., and tin at the rate of 1 oz. per lb. of mixed acids.

Tin solution is used for very similar purposes to red cotton spirits, from which it is not distinguished by any well-marked outline. Such a solution is made with 6 gal. hydrochloric acid at 32° Tw., 1½ gal. nitric acid at 64° Tw., 1 gal. water, and 7 lb. tin in rods. In working, the action should be brisk, and the surface of the liquid be covered with a small fine froth; but there must be no orange vapours.

A purple cotton spirit is made by mixing 5 lb. hydrochloric acid and 1 lb. nitric acid, both of the usual strength, and dissolving 2 oz. tin per lb. of mixed acid. Afterwards, ¼ lb. bichromate of potash, dissolved in water, is added to every 18 gal.

Printers' Oxymuriates.—(1) Hydrochloric and nitric acid, 20 lb. each; sal ammoniac, 5 lb., previously dissolved in the nitric acid; and dissolve in the mixture 10 lb. tin. (2) Melt 16 lb. tin crystals in a bowl set in hot water, and add by degrees 20 lb. nitric acid. (3) Melt in the same way 60 lb. tin crystals, adding 1 qt. water, and add gradually 92 lb. nitric acid at 60° Tw. (4) Hydrochloric acid at 34° Tw., 11 lb.; nitric acid at 62° Tw., 5 lb.; and dissolve gradually 2 lb. feathered tin. No. (2) is used for "cutting" madder pinks, and No. (4) for spirit styles.

Pink salt is a double chloride of tin and ammonium. It is precipitated as a white powder, if a strong solution of the stannic chloride (bichloride or perchloride of tin, free from nitric acid) is mixed with a saturated solution of sal ammoniac. Its uses have not been fully studied.

Stannate of soda, otherwise known as preparing-salt, is very extensively used in the steam-style of printing, and may also be used in fixing certain dyes, including aniline colours, upon cotton. It is generally made according to Young's process: good tin-ore, i. e. oxide of tin free from certain impurities, is heated to about 316° (600° F.), either with caustic soda or with a mixture of nitrate of soda and common salt, while a current of steam is passed over the mass. The whole, when cold, is dissolved in water, let settle, filtered, and boiled down.

To determine the proportion of tin in a sample, weigh out a known quantity, dissolve it in water, add a few drops of hydrochloric acid, and place in the solution some pieces of clean sheet zinc. By the action set up, the tin is thrown down as a metallic sponge. It is collected, washed in distilled water, dissolved in pure hydrochloric acid, and its quantity is ascertained by the method given above for tin crystals.

It is a great mistake to suppose that the comparative value of two samples of stannate of soda, or indeed of any other compound, can be ascertained by dissolving equal weights in equal measures of water, and taking the sp. gr. by Twaddle's or Beaumé's hydrometer. Common salt, which is sometimes found in stannate to the extent of 28 per cent., raises the hydrometer, though it adds nothing to the value of the sample. Many compound stannates have been proposed in which arsenic, phosphorus, alumina, silica, and tungsten are used in place of a portion of the tin. Concerning these mixtures, the general opinion of the trade is not favourable.

Zinc Mordants.—The soluble salts of zinc, such as the nitrate, chloride, and acetate, are occasionally used in printing, but very rarely as true mordants. The addition of chloride of zinc to the crystals, which has been recommended with the view of forcing the tin upon the fibre, has not established a success in practice.

Organic Mordants.—Next come a number of bodies having little in common, save the property of fixing colours upon tissues; but which do not, like the bulk of the substances above mentioned (silica and sulphur being the only exceptions), form "lakes," if brought into contact with solutions of colouring matters. Among these bodies, the first to deserve mention is argol, otherwise known as tartar, or cream of tartar (potassium bitartrate). This substance, which consists of tartaric acid in combination with potash, is deposited from the juice of the grape in wine-tuns, and is sold in various grades of purity as red argol, white argol, grey tartar, and crystal tartar. It is very extensively used in woollen-dyeing, along with alum, salts of tin, chrome, &c., and would be employed more extensively were it less expensive. The question whether tartar is a true mordant, or an alterant—serving to modify rather than to fix colours—has been debated with some warmth, and is scarcely decided.

A variety of substitutes for tartar and argol under such names as pro-tartar, pro-argol, tartar-spirits, &c., some of them containing a proportion of tartaric acid, and others being mainly mixtures of bisulphate of soda, common salt, &c., have been used more or less; but their success is by no means unequivocal.

A very important part as mordants is played by the astringents. (See Tannin.)

The animal mordants are chiefly albumen, caseine, and gelatine. If applied to linen, cotton, or other vegetable fibre, they give it the property of taking up colours in the same manner as is done by the animal fibres, silk, wool, &c. The cotton, &c., is then said to be animalized, and can be dyed with magenta, picric acid, &c., without the aid of any ordinary mordant. In other cases, as in the so-called pigment style of calico-printing, the animal mordant in a liquid state is ground up with the colour to be applied, printed upon the fibre, and then rendered insoluble by some appropriate means.

Among these animal mordants, the principal place is due to albumen, the finest quality of which is white of egg, an article necessarily limited in quantity, and very costly. Albumen from blood, if well prepared, can be used for all but the very lightest and brightest colours. It is said that blood-albumen, perfectly colourless, and equal to the finest egg-albumen, has recently been produced in Germany. The albumen from the roe of fishes, and from certain molluscous animals, cannot be readily made available, on account of the difficulty of removing accompanying substances. Albumen in its natural state is soluble in water, but is rendered insoluble if heated to 71° (160° F.), a property which thus supplies an easy method of fastening it permanently upon the fibre. It is also coagulated and fixed by tannin, and by sugar of lead.

Caseine agrees very closely with albumen in its chemical composition, but differs from it in several of its properties. In dilute solutions, it is not rendered insoluble by the action of heat. For use, caseine is dissolved in an alkali, generally ammonia, in which case it may be permanently fixed upon the fibre by means of evaporation. It is to be regretted that, in an English patent for the use of caseine as a mordant, it received the utterly needless and unscientific name of "lactarine," to which the trade still cling.

Gelatine or glue in its various forms is also used as a mordant, though it is not well adapted for the pigment style of printing. It is generally, when required, fixed upon the fibre by a subsequent treatment with some astringent, such as decoction of nut-galls.

Another class of organic mordants consists of oily or fatty bodies. Oil has for centuries been found necessary in fixing the colouring-matter of madder (natural alizarine) upon vegetable fibre in the brightest and most permanent condition.

For such purposes, not all oils are suitable, but merely those kinds which are emulsive, i. e. which, if shaken up with a solution of pearl-ash or soda-ash, form a white, milky fluid, from which the oil does not separate for some time.

This property can be communicated to oils, otherwise suitable, by the addition of a proportion of oleic acid, or by treatment with sulphuric acid, which is afterwards neutralized or otherwise removed. Oil mordants are applied to the yarn or cloth in the cold by means of padding, the goods being then spread out to the air. This alternate process is repeated several times.

The following method has been recently adopted for preparing an oil mordant for dyeing with alizarine. Take 3000 parts of castor-oil and pour into it, in a thin stream, and with continual stirring, 650 parts oil of vitriol, in such a manner that the process of mixture may last for 3 hours, and that no rise of temperature may take place. The mixture is then left to stand for 12 hours, and is next diluted with 3500 parts of water. Then about 650 parts soda-ash, more or less according to its strength, is added by small portions at a time, till the liquid no longer reddens blue litmus-paper. In this state, it forms a white emulsion, if shaken up with water. If it is desired to avoid this property, ammonia is added by degrees, till a portion of the mixture drawn out dissolves in distilled water, without causing any turbidity. It is then allowed to settle, and after standing for 12 hours, the oil may be drawn off for use. A deposit of crystals of sulphate of soda remains at the bottom of the vat. The product obtained is a sulphoricinoleate of ammonia.

A more complicated process has been patented by Dr. A. Müller-Jacobs, who proceeds as follows:—He heats castor-oil with $\frac{1}{5}$ its weight of oil of vitriol, poured in as a slender stream. This part of the process is conducted in lead-lined iron tanks, traversed by coils of lead piping, in which, if needful, ice-cold water can be made to circulate, to prevent heating. After standing for 2–3 hours, the mass is diluted with water, and neutralized with a lukewarm solution of soda (28 lb. soda crystals to every 10 lb. acid which has been used). This alkaline solution is added very slowly, and with constant stirring. The liquid is then allowed to stand over-night, and the next morning it is found separated from the saline mother-liquid, and is drawn off for use.

Meantime pyroterebate of soda is prepared by boiling in an enamelled iron vessel 100 parts rosin with 250 parts nitric acid, the rosin being added gradually, and in powder. After 1½ hour, the mass is gradually evaporated, and the residue is heated for ½ hour to 200°–311° (392°–522° F.) in a closed iron vessel. When cold, it is heated with 20–30 per cent. of its weight of oil of vitriol; then, after the lapse of 2–3 hours, neutralized with soda, and the sulphopyroterebate of soda is reserved for use.

To make the oil mordant, equal measures of the sulphoricinoleate and of the sulphopyroterebate are mixed, and are at once fit for use.

The applications of oil mordants, both in dyeing and printing, will be found capable of further development. Various attempts have been made to use oils as a medium for the fixation of pigments in printing. The difficulty to be overcome is the tendency of the oil to spread in the fibre. This is to be prevented, without interfering with its transparency, or darkening its colour. O'Neill has obtained very satisfactory results on a small scale, but by processes which he considers too delicate and costly for actual practice.

Soaps are not unfrequently employed for fixing artificial colours upon the fibre, but almost invariably in conjunction with ordinary mordants, such as alum, red liquor, or compounds of tin and lead. In such cases, the result is that a compound of alumina, lead, or tin, with the fatty acids of the soap—in other words, an insoluble metallic soap—is deposited upon the fibre.

Mordants at the best must be regarded as necessary evils. One of the greatest triumphs of tinctorial chemistry would be the production of a complete scale of substantive colours, available on every kind of fibre. Many steps have already been taken in this direction. W. C.

(See Acid [Acetic]—Iron, Acetates of; Albumen; Alum; Alumina; Dyeing and Calico-printing.)

NARCOTICS (Fr., *Narcotiques*; Ger., *Schlafmittel*).

The term "narcotic" is applied to a class of drugs, which, in medicinal doses, allay morbid susceptibility, relieve pain, and produce sleep; but which, in poisonous doses, create stupor, coma, convulsions, and even death. The physiological effects of the various narcotics are always essentially different, each possessing its own marked peculiarities. Though the use of narcotics is regarded as an indulgence rather than as supplying any real want, it is remarkable that almost every country or race has its own, either indigenous or imported, pointing to the universal existence of the craving.

The chief narcotic, because most widely used, is tobacco; next in order come opium, hemp, and coca. These are the most important. Of minor significance, are ava or long pepper, betel-pepper, bull-hoof, emetic holly, ledum, pituri, rhododendrons, Siberian fungus, Syrian rue, thorn-apples, and tumbeki. All these will be described in alphabetical order in the present article. Another class of products possessing narcotic principles, noticed in other portions of this work, are belladonna, cocculus indicus, henbane, and lactucarium (see Drugs, pp. 794, 808, 812, and 815); and hops (see Hops, p. 1130). A fourth series, whose members are too insignificant to warrant any description, comprises clary, yarrow, ryle, sweet gale, Armenian azalea, *Kalmia spp.*, *Andromeda spp.*, &c.

Ava, Kava-kava, or Intoxicating Long Pepper.—The leaves of *Piper methysticum* are chewed along with the betel-nut, instead of those of the betel-pepper, in many parts of Further Asia. The thick, woody, rugged, aromatic root-stalk, reduced to a pulp, and steeped in water, forms an intoxicating yet most refreshing beverage in the South Sea Islands. For its medicinal uses, see Drugs—Kava-kava, p. 815.

Betel-pepper, Betel-leaf, or Pawn.—The leaves of *Piper* [*Chavica*] *Betle* and *P.* [*C.*] *Siriboa* are used in conjunction with betel-nut as a narcotic masticatory throughout a large portion of the East. It is very generally cultivated. The plantations are laid out like bean-fields, the plants standing 18 in. apart, and requiring much water. They are trained up poles for the first eighteen months, and are then directed around fast-growing young trees, planted meanwhile. The leaves are gathered in the 3rd–4th year, and the plants bear for 6–7 years, after which they die. In N. India and towards the Himálayas, where the climate is moist enough, the plants are raised under sheds, 20–50 yd. long, 8–12 yd. broad, and scarcely 4 ft. high, made of bamboo, wattled all around and on the top. Slender rods are provided for them to climb up. This mode of cultivation is profitable, and extensively prevails, though twenty-four hours' exposure to the open air would kill the plants. There seems to be much probability that the narcotic effect of betel-chewing is due much more to these leaves than to the betel-nut (see Nuts—Areca).

Bhang, Charas, Ganja, Hashish.—The sap of the hemp-plant (*Cannabis sativa*), well known in Europe as producing a valuable fibre (see Fibrous Substances, p. 934), contains a powerful narcotic principle. This principle is doubtless present to some degree in the plant wherever grown; but in northern climates, its proportion is so small as to have escaped general observation, and that which does exist is very mild in character. In the warmer countries of the East, it is developed in a marked degree in the flowers, leaves, and young stems of the plant, and is the object for which the plant is grown. Its cultivation is largely and systematically conducted in the districts of Bogra and Rájshábi, north of Calcutta; even more widely in Turkestan, and most of the trans-Himálayan countries; also in Persia and Turkey, and throughout Mohammedan territory generally; and the use of the narcotic has extended to the Hottentots in S. Africa, the negroes of W. Africa, the Indians of Brazil, and the Malays. It is consumed in one form or another by 200–300 millions of people, chiefly Mohammedan and Hindu.

The chief constituents of the commercial narcotic are a resin and a volatile oil. The resin is obtained as a brown amorphous solid, and seems to be the seat of energetic action. Its effect is so potent that $\frac{2}{3}$ gr. taken internally suffices to produce narcotism, and 1 gr. causes complete intoxication. Dr. Preobaschensky states that he has separated the narcotic principle as an alkaloid, and makes it identical with nicotine, but his observations do not seem to have been verified. The oil is obtained only after repeated treatment of successive quantities of the plant in the same water. Freshly gathered plants just after flowering have afforded 0·3 per cent. of this oil, which possesses some active properties. The narcotic receives its various names according to the portion of the plant which yields it, and the method of preparation. These will now be described.

BHANG, SIDDHI, or SABZI, consists of the larger leaves, seed-capsules, and small stalks, in a dried state, coarsely broken, of dark-green colour, with a few fruits intermixed, of peculiar but not unpleasant odour, and almost tasteless. The leaves are gathered before any other portion of the plant is harvested; the stalks, &c., are accidentally present. Locally, it is smoked with or without the admixture of tobacco, or is made into a sort of confection, or a cold-water infusion is taken as an aromatic beverage. Very large quantities of the narcotic in this form are received into India from Turkestan; it also occurs as a commercial article in the London drug sales.

CHARAS, CHURRUS, KIRS, or MOMEEA, are the various names applied to a resin which exudes in minute drops from the foliage of the plant. The degree in which this resin is produced varies greatly: in India, it is copiously afforded by the plants grown at an altitude of 6000–8000 ft., but cannot be obtained from those cultivated in the plains. The plants exhibiting greatest richness in this resin in the Laos country of the Malayan Peninsula do not exceed 3 ft. in height, and have densely curled leaves. The manner in which the resin is collected is subject to variation. In Nepal, it is gathered by rubbing the tops of the plants between the hands when the seeds are ripe, and scraping off the adherent substance. This variety is very pure, and is called *momeea* or "waxen" *charas*; it remains soft, even after continued drying. In Central India, men wearing leather aprons pass rapidly among the plants, brushing violently against them, by which the resin is detached, and caught upon the apron, whence it is periodically removed. The ordinary kind from Cabul is obtained in the same way. In some districts, the coolies dispense with the leather apron, and collect the resin upon their naked bodies. In Persia, the plants are pressed upon coarse cloths; the resin is subsequently scraped from these, and melted in a little warm water. Such is the *kirs* of Herat, one of the best and most powerful varieties of the drug. Much resin is dislodged when heaps of dried *bhang* are stirred about; this is carefully collected, due precaution being observed against the effects of the dust upon the human constitution. The best Yarkand *charas* is a brown, earthy-looking substance, in irregular masses, made up of minute, transparent grains of brown resin; other specimens appear like a dark, compact resin. Crystalline structure is revealed by the microscope. However obtained, it is considered a crude form of the narcotic, and is not admitted into European pharmacy. In India, it is chiefly consumed by smoking with tobacco. For this purpose, very large quantities are exported from Yarkand and Kashgar, through Leh, into Kashmir and the Punjab. Yarkand, in 1867, thus despatched 1830 *maunds* (146,400 lb.). In 1876, Afghanistan sent 86,000*l.* worth through the Khyber Pass into British India. Kandahar and Samarkand contribute smaller quantities; and some seems to be exported from Mandchuria to China.

GANJA, GUNJAH, or GUAZA, the last being the corrupted name used by the London drug-brokers, is applied to the shoots of the female plant, gathered while in flower or fruit, and dried without removal of the resin. In the Calcutta markets, these are sold in bundles, about 3 in. in diameter, containing 24 plants. The shoots vary in succulence and in length; they have a compressed and glutinous appearance, are very brittle, and brownish-green in colour. Boiled in alcohol, *ganja* yields $\frac{1}{5}$ of its weight of resinous extract. Its convenience in this respect makes it best adapted to the needs of European medicine, and it is therefore the form in which we most generally import the drug. In India, it is smoked like tobacco, and often in admixture with it. In Morocco, the dried flowers are smoked, under the name of *kief*. In Africa, it is known as *djamba*, and is found in the markets packed in strips of palm leaf, or husks of maize, generally about 2 ft. long, tied at top and bottom, and at intervals of about 1–1½ in. throughout the whole length of the case. When required for use, one division is cut through, and suffices for one pipe. The packages are sometimes smaller, and the charges not larger than a marble.

Hashish, Dawamese, Madjoun, and **El Mogen,** are various forms in which the narcotic is prepared. Hashish, which is by far the most common, is made by boiling the leaves and flowers of the hemp-plant in water containing a little fresh butter, evaporating down to a syrupy consistence, and straining through cloth. The butter extracts the narcotic principle, and assumes a greenish colour. The preparation retains its properties for many years, and becomes but slightly rancid. For use, it is compounded with confections and aromatics, and forms the basis of the *el mogen* of the Moors, and the *dawamese* of the Arabs. The *madjoun* of Constantinople and Algeria is composed of the pistils of the flowers, ground to powder, and mixed with honey and spices. In Central Asia, the article occurs in the bazars in the form of cakes of various shapes, mostly 5–15 in. long, 5–10 in. broad, and 1–3 in. thick, dark-brown externally, greenish internally, firm, very tough, but easily cut into shavings. These cakes are prepared from the resinous juice of the fresh, unripe flower-tops, collected during spring, mixed with sand and water to a doughy consistence, spread upon a clay surface, and dried till cohesive.

Bull-hoof, or Dutchman's Laudanum.—The flowers of *Murucuja ocellata* [*Passiflora Murucuja*] are used in Jamaica, either infused, or mixed in a powder with wine or spirits, as a safe and effectual narcotic.

Coca, Cuca, or Khoka.—The name "coca" is a corruption of the Aymara Indian word *khoka*, which latter might well be resuscitated, in order to avoid the confusion now often made between this narcotic substance and the cocoa (cacao), and coco- (coker-) nut respectively. It is a product of one species of the genus *Erythroxylon*, the majority of whose species are natives of S. America and the W. Indies, and is called *E. Coca*, the specific name being derived from the product which distinguishes the plant from others of the same genus. It is a shrub or small tree, attaining a height of 4–8 ft. (usually about 5–6 ft.), and bearing a general resemblance to the blackthorn. It is a native of the tropical valleys occurring on the eastern slopes of the Andes, in Peru and Bolivia, and is also found in a lesser degree in Brazil, Ecuador, Venezuela, New Granada (Colombia), and Guiana, and is doubtfully mentioned as existing in the W. Indies. At Templado, in the Sierra Nevada of Santa Marta, Colombia, large quantities of coca (locally called *hallo*) are grown, and sent to the Goajira.

In many parts of the Andes, the shrub flourishes in a wild state, but in the inhabited districts, it forms an important agricultural crop, and the steep sides of the valleys, as high up as 8000 ft. above sea-level, where the mean temperature is 18°–20° (64°–68° F.), are often covered with *cocales*, or coca-plantations, forming the principal wealth of the settlers. The cultivation is commenced by sowing seeds in garden beds (*almacigas*) at the end of the rainy season (about 1st March in Peru). Maize is sown between the rows, to screen the young shoots from the sun, and maintain the soil in a moist condition, often the additional care is bestowed of placing arbours of palm-leaves over them; and watering must be attended to if the weather remains dry for a week or so. When 1½–2 ft. high, and 18 months old, the shoots are transplanted to holes on hill-side terraces, or to furrows on level ground. The usual distance apart is 18 in. each way. The ground must be carefully weeded. The plants thrive most luxuriantly in hot, damp situations, such as forest clearings; but the alkaloid principle for which the leaves are valued is more copiously developed when drier hill-side localities are chosen. The first crop of leaves may generally be taken 12 months after the transplantation, or in September, when the plants will be 2½ years old. This will be only a small picking; but 6 months later, the shrubs will be in full bearing, and will yield 3–4 crops of leaves yearly, according to the suitability of the locality, and the care taken in watering, &c. Usually there are 3 pickings—the first and most abundant in March, after the rains, the second in June, and the third in September–November. With due attention, the shrubs will continue productive for 40 years. Ants appear to be great enemies to them.

The leaves are narrow, and 2–3 in. long, tapering at the extremities, and of a lively green tint when fresh. When ripe, which is known by their cracking or breaking off when bent, they are carefully stripped from the branches by women, and sun-dried. The latter operation needs especial care. The green leaves (*matu*) are spread in thin layers on coarse woollen cloths, stretched upon prepared earthen or cement floors, after the manner of the "barbecues" used in coffee-drying, and exposed to the heat of the sun; when perfectly dry, they are pressed into serons, or skin bags. Every precaution must be taken to prevent their imbibing any moisture during exposure, and to ensure their not sweating either then or subsequently. Well-cured leaves are uncurled, of a deep-green colour on the upper surface, and grey-green beneath, with a strong tea-like odour and pleasant pungent taste, and produce a sense of warmth when chewed; inferior ones are dark-coloured, with a less agreeable camphoraceous smell, and are almost devoid of the pungent flavour and physiological effect.

About 100 plants are reckoned to yield 1 *arroba* (say 26 lb.) of leaves at a crop. The total yearly produce averages about 800 lb. of dried leaves from an acre; occasionally it amounts to 50 per cent. more, but often also it is much less. Altogether probably 30 million lb. of the dried leaves are produced annually, for the consumption of some 8–10 million people; this implies an area of nearly

40,000 acres occupied by the culture. The best districts appear to be the eastern slopes of the hills in northern Bolivia. The great centre of production is the province of Yungas, in the Department of La Paz, embracing the low tropical region below 5000 ft. A very large trade in the leaves is carried on at most of the towns in Bolivia and Peru, but Totora appears to be the principal depot.

In Bolivia and Peru, the Indians masticate the leaves in combination with an alkaline substance. Most commonly, the alkali takes the form of pulverized quick-lime; but in Cerro di Pasco, and places still further south, this is replaced by the pungent ashes of the quinoa (*Chenopodium Quinoa*), and sometimes a little tapioca is added. In Brazil, the leaves are dried, and reduced to powder in a wooden mortar along with the ash from the burnt leaves of *Cecropia peltata*. Occasionally the leaves are infused, and the tea-like beverage is drunk; but far more generally the compound of leaves and alkali is chewed like a quid of tobacco. The physiological effect is stimulating rather than purely narcotic, increasing the nervous energy, preventing fatigue, assuaging hunger and thirst, and rendering respiration easy at altitudes and under conditions otherwise most trying. It is therefore recommended for athletes, and should be invaluable to troops on the march or before action. Its use in excess is accompanied by the usual ill effects of too great indulgence in all narcotics. The substance is now known in European medicine and commerce. The dried leaves suffer much deterioration by the sea-voyage, and give unreliable results; but the fluid extract prepared from the fresh leaves, and imported in bottles by Christy & Co., Fenchurch St., seems to retain its full virtues. The properties of the plant are due to an alkaloid, called "cocaine," which has been shown to bear strong analogy to the alkaloids of the dietetic beverages—tea, coffee, cocoa, guarana, &c.

Emetic Holly.—An infusion or decoction of the leaves of *Ilex vomitoria* is the narcotic beverage of the indigenes of Florida. Little or nothing is known of its active principle.

Ledum.—The leaves of the marsh ledum or wild rosemary (*Ledum palustre*), a heath-plant common in N. Europe, were formerly used in Scandinavia and N. Germany, for giving bitterness and headiness to malt-liquors. The broad-leaved ledum (*L. latifolium*) possesses identical properties. In N. America, both are known as "Labrador tea," and are largely used as a beverage. The former is probably the better for this purpose. They deserve further investigation.

Opium.—This well-known narcotic is the concreted juice obtained from the fruits or "heads" of the so-called "opium-poppy" (*Papaver somniferum*), an annual plant of several varieties. The principal are:—(1) var. *α. setigerum* (*P. setigerum*), a truly wild form, occurring in the Peloponnesus, Hières, Cyprus, and Corsica; (2) var. *β. glabrum*, cultivated chiefly in Asia Minor and Egypt; (3) var. *γ. album* (*P. officinale*), cultivated in Persia, India, China, &c. The petals of these varieties range in colour from white to red or violet, with generally a dark-purple spot at the base. In England, the white-flowered are preferred. The seeds vary from white to slate-coloured.

The climatic conditions necessary to the successful culture of the poppy for its yield of opium are to be found throughout a very wide area, and the collection of the narcotic is possible in all temperate and sub-tropical countries which are not subject to excessive rainfall. Numerous experiments made in England, France, Germany, Switzerland, Italy, Greece, and even Sweden, have proved that a rich opium, equal to that of the East, can be produced in most parts of Europe. Grown in moist rich ground, in England, the heads attain double the size (3 in.) of those from Asia Minor and India. French opium has yielded the highest percentage (22·8) of morphine yet observed; and at Clermont-Ferrand, a pure inspissated juice, called "affium," containing 10 per cent. of morphine, has been produced for many years. Experimental culture in the neighbourhood of Amiens showed that 14,725 capsules incised within 6 days gave 431 grm. of milky juice, affording 205 grm. (47·6 per cent.) of dry opium, containing 16 per cent. of morphine.

Opium has been produced in Algeria. The cultivation of the poppy is being established in E. Africa; 50,000 acres of land in the Mozambique or Zambezi territory have been sown with the best Malwa seed, and a 12 years' monopoly has been granted to the cultivators. The plants thrive well, and their fruits are much larger than in India. In several of the United States, notably Georgia, Virginia, Tennessee, and Philadelphia, the culture of the opium-poppy has been initiated. The alluvial soils are best. The seed is sown in drills 3 ft. apart, and 12–18 in. between the plants, in July–August, the winter having no injurious effect (in Virginia). The ultimate success of the industry seems to be regarded as certain by American agriculturists, an excellent product having been obtained. The Australian climate seems very well adapted to the growth of the poppy, and opium of superior quality has been produced in Victoria; in 1878–9, 3 acres were occupied by this crop, yielding 60,000 heads.

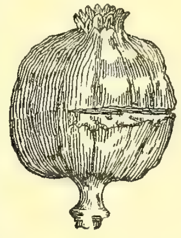
Production and Commerce.—Yet in spite of the wide adaptability of the plant, and the still wider employment of its valuable products, the cultivation has become of importance only in those countries which afford land and labour in abundance and cheapness, and where the narcotic is in popular use as such. Thus it happens that the commercial production of opium is limited to Asia Minor, Persia, India, China, and Egypt. As the varieties of poppy grown, the modes of cultivation of the plant, and the preparation and quality of the narcotic product, vary in these several countries, it will be convenient to consider each separately in the order just mentioned.

In Asia Minor.—The poppy cultivated in Asiatic Turkey is var. β. *glabrum*; its flowers are commonly purplish, but occasionally white, and its seeds are coloured white to dark-violet. The crop is raised both on the elevated and on the lower lands. None is more uncertain, spring frosts, droughts, and locusts causing it frequent injury, and sometimes complete destruction. The soil chosen must be naturally rich and moist; large quantities of manure are required, and the land is frequently ploughed till it has attained a thoroughly pulverulent condition. Moisture is indispensable, but is injurious when in excess. Consequently, after a wet winter, the best crops are got on the hilly grounds; in a dry season, on the plains. The seed, mixed with dry sand to avoid casting it too thickly, is sown broadcast. The sowings take place at three distinct periods, the objects being to obviate the chance of a total failure of the crop, and to ensure different portions of the crop maturing in succession. Without the latter precaution, the labour-supply would be quite insufficient; and even in spite of it, quantities of the drug are wasted when the crop is a full one.

The first and principal sowing, to which somewhat more than a half of the total available land is devoted, usually begins after the first winter rains, varying from October till November, and is sometimes postponed even later on in the high lands. This sowing is termed *giuzmaly*, or "winter sowing," and affords the hardiest plants, from their having greater time to establish themselves. In fact, no subsequent sowings compensate for the loss of this crop. A second sowing takes place in December–January, should the weather be sufficiently mild to encourage it. In favourable years, the returns from this sowing (*kishmaly*) nearly equal those from the winter sowing; but they are so uncertain that but little reliance can be placed on them. A third and important sowing is performed in the spring, February–March. Land is always reserved for this, the *yazmaly*, as a means of partially redeeming any loss entailed by the failure of the *giuzmaly*; but exceptionally favourable weather is required to make it a success. When delayed by the weather till March–April, it is an almost certain failure. The quantity of seed required is estimated at ¼–⅓ *oke* (say ¾–1 lb.) for every *toloom* (1600 sq. yd.). After sowing, the land is harrowed by means of the rough native implement, consisting of a few planks fastened together, and weighted by the driver standing upon it. In the early spring, when the plants of the *giuzmaly* have acquired some strength, hoeing and weeding commence, and are continued till the flowering season. These operations devolve upon the women and children of the proprietor, almost the whole cultivation of opium in Asia Minor being in the hands of a landed peasantry.

By about the end of May, the plants in the low lands arrive at maturity, and the flowers expand; on the uplands, this does not happen till July, owing to a reduced temperature. Gentle showers at this critical period greatly increase the yield of opium. The operation of extracting the latter from the capsules or "heads" of the plant commences when these are matured. This condition is reached a few days after the petals of the flowers have fallen off, and is further marked by the capsules changing to a lighter green hue. While the capsules are still quite green, and at that time about 1½ in. in diameter, they are subjected to incision for the purpose of liberating the juice. The operation is performed by drawing a knife around the head, generally at about the centre, and extending horizontally over about ⅔ of the circumference, or carried spirally till it overlaps itself by about ½. This horizontal (or nearly so) incision (Fig. 998) is adopted as affording less trouble in scraping off the subsequent exudation, and some assert that it cuts the greatest number of the vessels whence the exudation takes place, though experiment seems to indicate that no essential difference in the quantity of the product can be detected from the various systems of cutting. In all cases, great nicety is required to prevent the knife penetrating the interior coating of the capsule, and causing some of the juice to flow inside and be lost. The incisions are made after the heat of the day; on the following morning, the capsules are found covered with the exuded juice. If there has been heavy dew during the night, the yield is greater, but the product is weaker and of dark colour; if dew has been wanting, the yield is less, but the colour is lighter. A shower of rain, always possible at this season, is nearly sure to wash away the whole crop that had been prepared. Windy weather is prejudicial, causing much dust to adhere to the exudation. This latter is removed from the head by scraping with a knife, and is transferred to a poppy-leaf held in the left hand. After every alternate scraping, the knife-blade is drawn through the mouth, that the saliva may prevent the adhesion of the juice. A proposal to substitute a vessel of water for this objectionable practice has not been adopted. Usually each head is cut but once; as each plant, however, produces a number of heads, which mature at intervals, the same field needs to be visited a second and third time. As soon as sufficient of the juice has been gathered on a leaf, a second leaf is wrapped around it, and the cake or lump thus enveloped is put for a short time to dry in the shade. No definite size or weight

998.



is observed for these cakes, which vary from a few oz. to over 2 lb.; but in some villages, the average is higher than in others.

The gathered opium in the crude cakes passes from the grower to the local merchant. Money is advanced by the latter to the former on the security of the standing crop; and when this crop is gathered, the debt has to be liquidated, either (optional with the growers) in money or produce at the opening prices. When the crops are all in, the growers and buyers meet before the *mudir* or governor of each district, to "cut" or arrange a mutually satisfactory price. Should the price named not meet with the approval of the growers, they must either liquidate their debts in money, or bring forward other buyers who are ready to redeem their bonds, and take the produce, otherwise the grower must accept the prices offered by their creditors. In the event of competition, the parties who made the advances are entitled to the preference at the prices named at the meeting.

The purchasers receive the opium in its soft, crude, natural state. Occasionally they pack it without subjecting it to any sophistication, for conveyance to a sea-port. More generally, however, the soft drug is manipulated with a wooden pestle, and powdered poppy-heads, half-dried apricots, turpentine, figs, inferior gum tragacanth (often used by the Jews of Smyrna), a compound formed of evaporated grape-juice thickened with flour, stones, clay, scraps of lead; &c., are mixed up with it. The manipulated article is made into larger masses, which are enveloped in poppy-leaves, and packed in cotton bags, sealed at the mouth. These bags are packed into oblong or circular wicker baskets, to the weight of 80–100 *chequís* (130–162 lb.) in each, quantities of the little chaffy fruits of a native dock (*Rumex ?* sp.) being placed between the cakes to prevent cohesion. The baskets are transported in pairs on mule-back to the port. On arrival, they are placed in cool warehouses to avoid loss of weight, and remain unopened till sold.

On reaching the buyer's warehouse, the seals are broken, and the contents are examined piecemeal by a public examiner in the presence of buyer and seller. All of suspicious appearance is cut out and thrown aside. The examination is not based upon any scientific method; the character is judged only by the colour, odour, appearance, weight, &c., of the sample, but so expert are these officials that their estimation is generally very correct. The classification appears usually to be three-fold:—(1) "Prime" or *yerly*, not so much a selected quality as the produce of certain (empirically) esteemed localities; (2) "current," the mercantile quality, and constituting the bulk of the crop; (3) *chiquinti* (*chicantee*), the inferior article rejected during the examination. A 4th quality might include the very bad and wholly spurious sorts. The strength and quality are reckoned in carats, 24 carats constituting pure opium; according to custom, the examiner must pass all which reaches 20 carats, consequently a wide difference in quality may actually exist in two baskets valued alike. After examination, the tare (including the chaffy fruits used in the packing) is taken. The fruits are afterwards returned to the buyer for packing his cases. These are made large enough to hold each the contents of one basket.

The average yield of a *toloom* of land may be stated at 1½ *chequís* (2·43 lb.) of opium, and 4 bush. (of 50 lb.) of seed, valuable for the oil (see Oils—Poppy-seed). A good full crop may give 3–5 *chequís*, and even 7½ is not unknown. The amount produced varies exceedingly on the same plot. Thus the actual crops from 1 *toloom* in 4 different years were 7½, ⅓, 2¼, and 4½ *chequís* respectively. An estimate of the average expense and result of cultivating 100 *tolooms* of land with opium, supposing labour to be procurable at ordinary wages, would give the subjoined figures:—

PRODUCE.

	Piasters.
100 *tolooms* of land—average yield of opium at 1½ *chequí* a *toloom* = 150 *chequís*, at 80 *p.*	12,000
Average yield of seed, 4 bush. a *toloom* = 400 bush. at 20 *p.*	8000
	20,000

EXPENSES.

	Piasters.	
Tithes, 10 per cent. on value of produce	2000	
Ploughing, 118 days, at 8 *p.*	944	
Manure, 5000 donkey-loads, at 1 *p.* a load	5000	
Seed, 36 *okes*, or 2 bush., at 20 *p.*	40	
Hoeing, weeding, &c., 400 days, at 8 *p.*	3200	
Making incisions, 200 days, at 8 *p.*	1600	
Gathering, 100 days, at 8 *p.*	800	
Collecting seed, 100 days, at 8 *p.*	800	
Cleaning, 100 days, at 8 *p.*	800	
Cattle food, &c.	240	
		15,424
Average gain to a grower		4,576

This statement must be regarded as approximative only. Presuming the grower should send his opium to Smyrna for sale, the cost would be as follows:—150 *chequís*, at 80 *p.*, 12,000 *p.*; packing charges, 20; inland duty at $5\frac{1}{10}$ *p.* a *chequí*, 825; carriage, 300; loss on money by bills 2 per cent., 240; factor's commission in Smyrna, 2 per cent., 200: brokerage, 1 per cent. on 100 *p.*, 100; total, 13,685 *piasters*. This shows a cost of 91·23 *p.* a *chequí*, to which add 9 *p.* for shipping charges to Europe, making a total of 100·23 *p.*; or, at the exchange of 110 *p.* per £ sterling, and the usual equivalent per *chequí* of 1·62 lb., it would cost 11*s.* 1*d.* a lb. free on board; add charges in England, insurance, freight, &c., 5*d.* = 11*s.* 6*d.*

The purest opium is said to be collected at Ushak, Bogaditch, and Simav; but the pieces are small and stick together, which makes them unsightly. The Karahissar produce is reckoned not so good, and the pieces are larger. The fancied superiority of the article from certain districts is proved to be only partially correct by the fact that the quantity sold under these particular names is often 3–4 times as great as the localities could produce. Formerly the only opium-growing districts in the interior were Karahissar, Konieh, Yerli, Bogaditch, and Balikesri, and the crop was usually about 2500–4000 baskets. The crop of the Karahissar district was estimated to fluctuate between the following figures, representing a "good fair" and a "full" crop respectively:—Karahissar, 400–500 baskets; Afion Cassaba, 50–100; Sandukli, 200–250; Sitchanli, 60–80; Karamuk, 25–30; Tzai, 30–40; Bolavadin, 50–60; Ushak, 250–400; Ishikli, 100–200; Ekmé, Takmak, Coullah, 100–200; Tzal, Baklan, 80–100; Simav, Ghediz, Eneòvassi, Taouchanli, 200–250; Kutayah, 40–50; Boladitch, Eskihissar, 30–50; Ak Shair, 250–300; Yalavatch, 250–300; Karagatch, Sparta, Bourdroun, 150–200; total, 2265–3110. The largest quantities are now produced in the north-western districts of Karahissar Sahib, Balahissar, Kutaya, and Kiwa (Geiveh), the last on the river Sakariyeh, running into the Black Sea. These centres send a superior quality by way of Ismid to Constantinople, the best it would seem from Bogaditch and Balikesri, near the Susurlu river. The chief northern centres are Angora and Amasia. In the centre of the peninsula, Ushak and Afion Karahissar are important localities, as well as Isbarta, Buldur and Hamid farther south; the product of these places is concentrated at Smyrna. The export of opium from Smyrna was 5650 cases, value 784,500*l.*, in 1871. Samsoon, in 1878, exported 19,865 kilo., value 31,784*l.*, to Turkey (Constantinople), and 1667 kilo., value 3000*l.*, to Great Britain. The crop of 1879 was an average one, amounting to about 5200 chests in Asia Minor. The cultivation has extended into several new districts in Anatolia; also in Thessaly, where very superior qualities are produced.

The names and qualities of opium as classified at Smyrna are as follows:—Bogaditch, Yerli, Karahissar, common, *talequale*, and *chiquinti*. It is bought and quoted at so many *piasters* ("good money," i. e. in silver *medjidiés* at 20 *p.*) the *chequí*. The approximate relative values may be given as:—"Karahissar," last year's crop, 250 *p.* a *chequí*; *yoghourma*, good quality, 225; *yoghourma* seconds, 210; *talequale* and *chiquinti*, mixed, 220. Since 1868, when the crop was very short, the demand has rapidly increased; in 1877–8, the consumption in America and on the Continent reached 6900 baskets, and in 1878–9, 6300. This fact has induced a widely augmented cultivation. The production in baskets, and price (min. and max.) in *piasters* a *chequí*, during the last 10 years, have been as follows:—1870, 4500, 250–285; 1871, 8500, 130–200; 1872, 4400, 160–220; 1873, 3200, 165–260; 1874, 2500, 130–274; 1875, 6300, 122–145; 1876, 3250, 137½–190; 1877, 9500, 122½–138; 1878, 6100, 120–145; 1879, 4200, 135–250.

The first baskets of opium reach Smyrna at about the end of May or beginning of June, but it is not safe to effect any shipments before the month of August, for the following reasons:—(1) too fresh opium is liable to get heated, (2) the *chiquinti* is not so easily detected, and (3) it suffers a loss of weight. Apart from agricultural causes, the crop of opium depends in a great measure upon the prices ruling at the close of a season, which influences the area of land sown; after a large crop, with low prices, a small crop, with high prices, is almost sure to follow, and *vice versâ*. The best time for purchasing is, as a rule, at the commencement of a season; with a small crop, however, the chances are often most in favour of the buyer at the end of a season, prices being affected towards the close by the coming crop.

"Turkey," "Smyrna," or "Constantinople" opium, the produce of Asia Minor, occurs in commerce in the form of indefinite masses, which, according to their softness, become more or less flattened, many-sided, or irregular, by mutual pressure in the packing-cases. The most usual weight is ½–2 lb. but it is governed by no rule, and varies from 1 oz. to more than 6 lb. The exterior is coated with fragments of poppy-leaves, and strewn with the dock chaff before mentioned, and is thus rendered sufficiently dry to bear handling. The consistence is such that the substance can be readily cut by a knife and moulded by the fingers. The interior is moist and coarsely granular, varying in colour from light-chestnut to blackish-brown. Fine shreds of the epidermis of the head are easily visible. The odour is peculiar, but not disagreeable; the flavour is bitter.

In Persia.—The variety of *Papaver somniferum* grown in Persia is γ. *album* (*P. officinale*), having ovate-roundish heads, containing white seeds. It is cultivated principally in Yezd and Ispahan, and partly in the districts of Khorasan, Kerman, Fars, and Shuster. The opium produced in Yezd is considered better than that obtained in Ispahan and elsewhere, owing to the climate and soil of the former place being better adapted for the growth of the drug. But the district of Yezd, notwithstanding the existence of a large cultivable area, is not capable of any considerable extension of the cultivation of opium, owing to the insufficiency of the means, both natural and artificial, of irrigation. Ispahan, however, differs from Yezd in this latter respect, as it abounds in streams and rivers, and is capable of greater extension of the cultivation of the drug. But the cultivation of cotton and cereals takes up a large part of these resources, and tends in no small degree to reduce the culture of opium. A few years ago, the profits of opium having attracted the attention of the Persians, almost all available or suitable ground in Yezd, Ispahan, and elsewhere, was utilized for its cultivation, to the exclusion of other produce. It was then supposed that opium cultivation would be indefinitely extended in Persia, but circumstances eventually showed that such could not be the case. These attempts, combined with drought and other circumstances, resulted in the famine of 1871–2. The costly experience then gained has made the Persians more careful in appropriating space for the cultivation of opium, yet it is being yearly extended to fresh districts, and about Shiraz and in Behbehan is now occupying much of the land.

From a consular statement of the fluctuations of the annual estimated produce of opium in Persia from the year 1868–9 to 1874–5, it appears that the largest product of any one year did not exceed 2600 cases, an inappreciably small quantity, and in 1874–5, it had fallen to some 2000 cases. In the following year, there was a further decline, the exports amounting to about 1890 cases. Since 1876–7, however, a reaction seems to have taken place; in that year, 2570 cases were exported from Bushire and Bunder Abbas alone. In the early part of 1877–8, the probable yield of the crop was estimated at 3500, but the actual number exported from Bushire and Bunder Abbas amounted to 4730 cases. In the year 1878–9, the amount produced was stated to have been 6700 cases, while 5900 were shipped from these ports. The probable yield of the crops of the year 1879–80 was estimated to be as follows:—Khonoar, about 950 cases; Kerman, 300; Yezd, 1000; Ispahan, 2400; Nereez, 400; Shiraz, 1300; Kazran, 100; Shuster, 100; making a total of 6550 cases. In addition, about 300 *shah mans*, or say 550 cases, were expected to come to Yezd from Herat, making the whole stock about 7100 cases.

The values (in rupees) of the opium exports from Persia during the year 1879 were:—From Bushire: 1,50,000 to England, 2200 to Zanzibar, 50,00,000 to China, total 51,52,200; from Lingah: 50 to the Arab coast of Persian Gulf, and Bahrein; from Bahrein: 50 to Koweit, Busrah, and Bagdad.

The system of cultivation does not call for any special remark; but it may be noted that the incisions in the heads are made in a vertical direction with diagonal branches. The crop comes to hand in May–June, and the greater part of the opium finds its way to the shipping-ports between September and January following. Since the attention of Persian merchants was attracted to the trade, about 25 years ago, there has been, with two or three exceptions, a gradual annual increase in the production of the drug, though not to such an extent as to be prominently noticeable. Now, the cultivation of the poppy and exportation of opium through Bushire and Bunder Abbas increases rapidly; the returns from Bushire for 1878 show an increase in value over the previous year of 1,754,000 rupees, the quality being also very superior to that of previous years. Great care is now taken to prevent adulteration, the chests containing the opium being occasionally examined by experts. When the Persian opium trade was in its infancy, the drug was sent in sailing vessels to Java, and thence re-shipped in steamers for Singapore and Hong Kong. The Dutch Government, however, having imposed restrictions at Java, Aden was subsequently selected as a port of trans-shipment, and later Suez, at which port no duty is levied for trans-shipment. The Persian Steam Navigation Co. now send occasional steamers from the Gulf to Galle for conveyance of opium, when a sufficient quantity is collected.

The strongest opium, called *teriak-e-arabistani*, is obtained in the neighbourhood of Dizful and Shuster, east of the Lower Tigris. Good opium is produced also about Sari and Balfarush, in the province of Mazanderan, as well as in the southern province of Kerman. The lowest quality, which is mixed with starch, &c., and sold in light-brown sticks, is made at Shahabdulazim, Kashan, and Kum. Quantities of opium are collected in Khokan and Turkestan. About 100 cases of opium in cakes are brought annually from Herat to the Yezd market. From Yezd also, a quantity of opium, prepared in the shape of small sticks and cylinders, is sent to Herat for consumption there. The whole produce of Ispahan and Fars is carried to Bushire. The produce of Khorasan and Kerman is taken to the Yezd market, and this, together with that of Yezd itself, is sent partly to Bushire and partly to Bunder Abbas. The Shuster opium is sent through Mohammerah direct, and sometimes viâ Bushire to Mussah for transmission to Zanzibar, but a part of it is supposed to be smuggled into the Indian frontier provinces viâ Mekran and Beloochistan. Small quantities of opium are said to be grown in Teheran, Tabreez, and Kermanshah, but these mostly find their way to Europe viâ Turkey, Smyrna being the port where it is mainly taken to, and where it is mixed with the local drug, and forwarded to the Continental markets. Some Persian opium is carried overland to China, through Bokhara, Khokan, and Kashgar; but the bulk now goes by sea. A considerable portion leaves the country by way of Trebizonde and Samsoon, principally for Constantinople, where it is worked up in imitation of the Asia Minor article, and adulterated; the remainder comes directly to Great Britain.

About five-sixths of the total produce of Persian opium is intended for China. The drug suitable for that market being required to be fine, prepared with oil, and not rich in morphine, permits of its being swelled up with foreign substances, and thus adulterated as far as practicable, while precluding discovery by the mode of testing or "touching" used in China. It is said that pure and superior opium, though not so finely manipulated, has been rejected in China, while the fine opium, containing admixtures, has found favour and fair market. The preparations made for the China marts being, say, of a quality of 80 touch (containing 80 per cent. pure juice and 20 per cent. foreign substance) yield 9–10 per cent. morphine. Persian opium for the Chinese markets, where it is now assuming great importance, is made up in cakes, varying in weight from ¾ lb. to 1½ lb., and in number from 96 to 192 or more, and these are packed in fig or vine leaves, and sometimes in poppy seeds or stalks, into cases containing each 10½–11 *shah mans*—a *shah man* (or more properly, *batman-i-shah*) being equivalent to about 13½ lb. The object in so packing in cases, as regards the weight, is that the contents, after the loss caused by drying up in course of transit, calculated at 5–10 per cent., may realize at its destination (China) 1 *picul* (133⅓ lb.). Another reason is that the weight is arranged for convenience of carriage by pack animals.

The drug despatched to London occurs in various forms, the most typical being a short rounded cone, weighing 6–10 oz. Sometimes it is met with in flat circular cakes, 1¼ lb. in weight. It is usually of firm consistence and good odour, and of a comparatively light-brown tint internally, the surface being strewn with fragments of stalks and leaves. Some is collected with the aid of oil, as in Malwa (India), as attested by the greasiness of the cone, and the globules of oil displayed on cutting it. The best samples give 8–10¾ per cent. of morphine, reckoned on the opium in its moist state. Very inferior, or almost altogether spurious, samples also come into this market occasionally; thus some of a soft, black, extractiform character has given only ½–3 per cent. of morphine, reckoned in the moist; and some very pale, in small sticks, wrapped in papers, afforded but 0·2 per cent.

In India.—The kind of poppy generally cultivated in India is the same as in Persia, *P. somniferum* var. *γ. album* (*P. officinale*), with white flowers and white seeds; but a red flowered and black-seeded kind is met with in the Himálayas. The principal opium-producing region of British India lies in the central tract of the Ganges, embracing an area about 600 miles long and 200 wide, and bounded by Dinajpur (Dingepore) in the east, Hazaribagh in the south, Gorakhpur (Goruckpore) in the north, and Agra in the west, thus including the flat, populous districts of Behar and Benares. In 1874, 330,925 acres in the former, and 229,430 acres in the latter, were under poppy-cultivation. The next important region embraces the broad table-lands of Malwa, and the slopes of the Vindhya Hills, in the dominions of the Holkar. According to one authority, the kind of poppy grown here is var. *β. glabrum*, as in Asia Minor and Egypt. The regions just indicated collectively afford the chief supplies of the drug obtained in India, and their products are commercially known as "Patna," "Benares," and "Malwa," respectively.

Outside these extensive regions, the amount of land under poppies is relatively very small, though on the increase. The plant is grown for its narcotic throughout the plains of the Punjab, but less commonly in the N.-W. provinces. In the valley of the Bias, east of Lahore, it is cultivated up to an altitude of nearly 7500 ft. Most of the outer districts grow the poppy to a certain extent, and produce a small quantity of indifferent opium for home consumption. But the drug prepared in the Hill States and in Kulu, is of excellent quality, and forms a staple article of trade for the region. Opium is also produced in Nepal, Bassahir and Rampur, and at Doda Kashtwar, in the Jammu territory, at the base of the Himálayas, south and south-east of Kashmir. From these districts, it is exported to Yarkand, Khutan, Aksu, and several Chinese provinces,—to the extent of 210 *maunds* (16,800 lb.), in 1862.

The opium industry in Bengal is completely under the control and monopoly of the Government. The districts producing the narcotic are divided between two agencies—one, the more important, for Behar, and having its head-quarters at Patna; the other, for Benares, at Ghazipur. Within these districts, anyone who chooses may engage in opium-culture, but is under an obligation to sell the produce exclusively to the government agent, at a price fixed beforehand by the latter. This price is approximately 3*s.* 6*d.* a lb., the article being sold by the government at about 11*s.* a lb. The profit realised by the government is thus enormous; but the peasant is well and fully remunerated by the price he receives, and engages in the culture solely of his own free will. The system has been called oppressive, but is really paternal; with greater freedom to the cultivators, probably over-production and loss would soon result.

In Malwa, the opium is free-grown, and is of immense importance to the people, giving a value to the land which no other crop can equal. Thus, while wheat and other cereals in the best soil pay 12 *a.*—3 *r.* a *beegah*, land under poppies gives 10–20 *r.* and even 40 *r.*, and in unusually advantageous positions, up to 60 *r.* a *beegah*. The produce is subjected to a heavy duty on entering

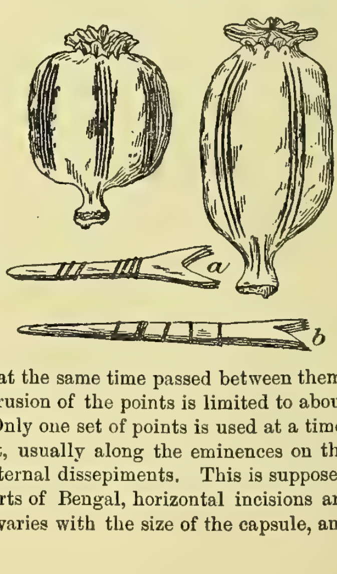
British territory. Formerly, Indore was the only place at which scales were established for levying this duty; but since the opportunity has been afforded of paying duty at Ujjani, Jaora, and Udepur, and the facilities of railway transit from Indore and Ujjani, the export has increased at the rate of 500 chests a month. The product goes to Bombay for shipment. Opium grown in the Bombay Presidency is subject to the same dues as that from Malwa.

The poppy is a delicate plant, and liable to many injuries from wind, hail, and unseasonable rain. Of late years, the Indian plantations have suffered from blight. Moist and fertile soil is indispensable; it was said in 1873 that the ground devoted to poppy-culture in Bengal was becoming impoverished, and that the plants no longer attained their usual proportions. Successful trials have been made of the effect of interchanges of seed between the agencies of Behar and Benares; but the experiments with Persian and Malwa seed resulted in failure.

The cultivation and preparation as conducted in Bengal are as follows:—The lands selected for poppy-culture are usually in the vicinity of villages, where the facilities for manuring and irrigation are greatest. On a rich soil, the cultivators often take a crop of maize or vegetables during the rainy season, and after its removal in September, prepare the ground for the poppies. Elsewhere, the poppy-crop is the only one taken throughout the year, and from the commencement of the rains in June–July, till October, ploughing, weeding and manuring are successively carried on. The final preparation, in October–November, consists in loosening the soil with a plough, and subsequently breaking down the surface to a fine condition by dragging a heavy log over it. The seed is then sown broad-cast about the 1st–15th November. After 3–4 days, the plough is passed over to bury the seed, and the surface is again levelled by means of a heavy log. It is then divided into square beds, measuring about 10 ft. each way, and with little channels between for purposes of irrigation. The amount of irrigation necessary depends upon the season: if some heavy showers fall in December–February, two irrigations may suffice; but in a cold season with little or no rain, it may need repetition 5–6 times. The seeds germinate in 10–12 days. After the plants have reached a height of 2–3 in., they are carefully weeded and thinned. In favourable situations, they vegetate luxuriantly, commonly attaining a stature of 4 ft. About 3½ months are required by the plant in arriving at maturity, the cultivation being restricted to the cold season, November–March. During growth, the plant has to contend with several enemies. It may be nipped by unusually severe frosts, or may be stunted through the failure of the first sowings, or through great heat and deficient moisture. The roots of many plants are attacked by a vegetable parasite, a species of broom-rape called *tokra* (*Orobanche indica*). Another fatal disease, termed *murka*, is attributed to an infusorial worm, which corrodes the tender roots. *Khurka* is a kind of blight arising from sudden excessive damp.

Towards the middle of February, when the plant is in full flower, and just before the time for the fall of the petals, these are carefully collected. They are then formed into circular cakes, 10–14 in. in diameter and $\frac{1}{16}$ in. in thickness, in the following manner:—A circular shallow earthen or iron vessel is heated by inversion over a slow fire. A few petals are then spread upon its heated convex surface, and as soon as their glutinous juice exudes, others are added to the moist surface, and pressed down by means of a cloth. This process is repeated with more layers, until the cake has reached the desired dimensions. These cakes of petals, technically known as "leaves," on reaching the opium factory, are sorted into three classes, according to size and colour. The small and dark-coloured "leaves" are used in forming the inner portions of the shells of the opium cakes, while the largest and least discoloured are reserved for the outside coverings.

999.



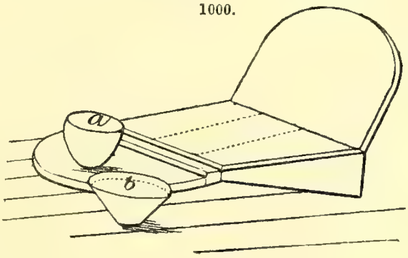
A few days after removing the petals, the poppy-heads or capsules are fully developed, and the collecting of the opium commences, lasting in Behar from 20th February to 25th March, in Malwa, March–April. The scarification of the capsules takes place at 3–4 p.m., and is performed by means of *nushturs*, bunches of (3–5) forked blades, about 6 in. long, and increasing from ¼ in. wide at the handle-end, to 1 in. at the blade (Fig. 999). The sides of the fork are sharpened and slightly curved. The blades are bound together with cotton thread, which is at the same time passed between them, so as to separate the cutting-ends by about $\frac{1}{16}$ in. The protrusion of the points is limited to about $\frac{1}{12}$ in., which thus determines the depth of the incision. Only one set of points is used at a time, and the incisions are made vertically, from base to summit, usually along the eminences on the outside of the capsule, which mark the attachment of the internal dissepiments. This is supposed to be the most effective way of scarifying; but in some parts of Bengal, horizontal incisions are adopted, as in Asia Minor. The number of incisions (2–6) varies with the size of the capsule, and

2–3 days are allowed to alternate. A little milky-white juice exudes almost immediately, and quickly becomes coated with a slight pellicle, from the solar heat. The exudation, evaporation, and inspissation of the juice continue throughout the night, and are affected by the same causes as elsewhere, already noted. The collection of the juice takes place early on the morning following the scarification. In Bengal, it is performed by a small sheet-iron scoop (*seetoah*), which is twice drawn briskly upwards over each incision, and is occasionally emptied into an earthen vessel carried for the purpose. In Malwa, a flat scraper is used; attached to the upper part of the blade, is a small piece of cotton soaked in linseed-oil, with which the thumb and the edge of the scraper are occasionally smeared, to prevent adhesion of the juice. This lowers its quality. A still worse practice is the use of water for the same purpose.

The stems and leaves of the poppies are left standing after the removal of the seeds and capsules, till perfectly dried by the hot winds of April-May, when they are gathered, and crushed into a coarse powder, termed "poppy-trash," used in packing the opium cakes. The collected juice, as brought home, consists of a wet, granular, pinkish mass, beneath which collects a dark coffee-like fluid, termed *pasewa* or *pussewah*. The whole is placed in a shallow earthen dish, tilted so that all the *pasewa* may drain off, for the latter injures the physical qualities of the opium, causing it to look black and liquid, while it gives the drug an artificially high assay when tested by evaporation. It is set aside in a covered vessel until taken to the factory. Meantime the more consistent portion, forming the opium proper, is exposed to the air in the shade, and regularly turned over, in order to ensure its thorough desiccation. This is continued for 3–4 weeks, or until it has reached within a few degrees of the standard consistence, which, in Benares, is a residue of 70 per cent. after evaporation at 93½° (200° F.). The price paid to the cultivator for his opium is regulated by this standard. On reaching the factory, it is turned out of the pots, and weighed in wide tin vessels (*tagars*) in quantities not exceeding 20 lb. It is then examined by a native expert (*purkhea*) as to impurities, colour, texture, fracture, aroma, and consistence; and a weighed sample is evaporated to dryness in a plate on a metallic surface heated by steam, for final determination of the value. The grosser adulterations are mud, sand, powdered charcoal, soot, cow-dung, powdered poppy-petals, and various powdered seeds. All these are physically discoverable by breaking up the drug in cold water. Flour, potato-flour, *ghee*, and *goor* (crude date-sugar), are often used; their presence is revealed by the odour and consistence they impart. Many vegetable juices, extracts, pulps, and colouring matters are occasionally added, e. g. the inspissated juice of the prickly pear, extracts from tobacco, stramonium, and hemp, gummy exudations, pulp of the tamarind and bael-fruit, and catechu, turmeric, and mowha flowers. The examination of the drug in a physical manner for the detection of these impurities is the only kind necessary, as the commercial criterions of its excellence are colour, aroma, and texture; the intrinsic value, i. e. the proportion of narcotic alkaloids present, is less regarded by the buyer.

When weighed into store, the opium is kept in large wooden boxes, holding about 10 cwt.; if below the standard, it is occasionally stirred up, to favour its thickening; and if very low, is placed in shallow wooden drawers, and constantly turned over. Whilst keeping, it becomes coated with a thin blackish crust, and deepens in colour according to the degree of exposure to air and light. From this general store (*malkhana*), it is taken daily, in quantities of about 250 *maunds* (of 82$\frac{2}{7}$ lb.), for manufacture into "cakes." Various portions are selected (by test assay) so as to ensure the mass being of the standard consistence, and these, weighing exactly 10 *seers* (21 lb.) each, are thrown promiscuously into shallow drawers, and rapidly and thoroughly kneaded up together. The mass is filled into boxes, all of one size, from each of which a specimen is drawn and assayed. The mean is taken as the average. Before evening, these boxes are emptied into wooden vats, 20 ft. long, 3½ ft. wide, and 1¼ ft. deep, and the opium is further kneaded and mixed by men wading knee-deep through it from end to end, till the consistence appears uniform.

1000.



Next morning the manufacture of the cakes commences. Each cake-maker sits on a wooden stand, and is provided with a brass cup and a graduated tin vessel (Fig. 1000). The "leaves" for forming the shells of the cakes are weighed out over-night, tied in bundles, and damped to make them supple; and boxes are provided containing *lewa*, for agglutinating the "leaves" to form the shells of the cakes. This *lewa* consists of an admixture of inferior opium, *pasewa*, and the washings of vessels that have contained good opium, forming a semi-fluid paste of such a consistence that 100 gr. evaporated to dryness at 93½° (200° F.) leave 53 gr. residue. The *lewa*, "leaves," and opium are accurately weighed out for each cake. In his brass cup, the operator rapidly forms the lower segment of the shell of the cake, pasting "leaf" over "leaf," till a thickness of ½ in. is reached, and allowing a certain free portion of the most external "leaves" to hang down around and over the sides of the cup. The cake of opium brought from the scales is now inserted, and held away from the sides with the left hand, while one "leaf" after another is tucked in, well smeared with *lewa*, and imbricated one over the other, till the circle is complete. The free portions of the "leaves" left hanging over are drawn up tightly, and the opium cake is well compressed within the casing. A small aperture remains at the top; this is closed by adding more "leaves," and finally the cake is completed by applying a single large "leaf" to the entire exposed half. The finished ball or "cake" resembles a Dutch cheese in size and shape. It is rolled in a little finely powdered poppy-trash, which adheres to its surface, is at once placed in a small earthen cup of the same dimensions as the brass cup used in shaping it, and is carried out and exposed in small dishes to the sun. It is so exposed for three days, and is meantime constantly turned and examined; should it become distended, it is opened to liberate the gas, and again tightly closed. On the third evening, still in their earthen cups, the cakes are placed on the "frames,"—open battens allowing free circulation of air. The operation thus far is terminated by the end of July. The constituents of the average perfect cake are :—

Standard opium	1 *seer*	7·50 *chittaks.*	
Lewa		3·75 ,,	
"Leaves" (poppy petals)		5·43 ,,	
Poppy-trash		0·50 ,,	
	2 *seers*	1·18 *chittaks*	= 4 lb. 3½ oz.

The number of cakes made by one man in a single day is about 70, though some can turn out 90–100. After manufacture, the cakes require much attention, and constant turning, on account of the mildew which attacks them. This is removed by rolling and rubbing in dry poppy-trash. Weak places are also looked for, and strengthened with extra "leaves." By October, the cakes are perfectly dry to the touch, and fairly solid; they are then packed in chests, furnished with a double tier of wooden partitions, each tier with twenty square compartments for the reception of so many cakes, which latter are steadied and packed around with loose poppy-trash. The chests must be most carefully kept from damp for a length of time; but ultimately the opium in the cake ceases to yield any more moisture to the shell, and the latter acquires extreme solidity. Each case contains 120 *catties* (about 160 lb.). The foregoing remarks refer exclusively to the Government-prepared opium for the Chinese market, which includes the great bulk of the entire product.

Bengal opium intended for internal consumption, and known as *abkari* opium. is prepared in the following manner :—It is inspissated by exposure to direct sun-heat till its standard is 90 per cent., and its consistence resembles wax. It is then moulded into square bricks weighing 1 *seer* each, which are wrapped in oiled Nepal paper, and packed in boxes furnished with compartments for their reception. Put up in this way, it has not the powerful aroma of the "cake" drug, but it is more concentrated, and more easily packed. It is sometimes also made into flat square tablets.

In Malwa, the cultivation and preparation of the drug are entirely in the hands of the natives. The details of cultivation are much the same as in Bengal; not so the preparation. The crude exudation (*chick*), as collected, is thrown into an earthen vessel, and covered with linseed-oil (2 parts oil to 1 part *chick*), to prevent evaporation. In this state, it is sold to itinerant dealers. Quantities of 25–50 lb. are tied up in double bags of sheeting, which are suspended from the ceilings, out of the light and draught, while the excess of oil drips through. This operation terminates in 7–10 days, but the bags are left for 4–6 weeks, by which time the oil that has not escaped has become oxidized and thickened. The whole process lasts from April till June–July, when the rains begin. The bags are then taken down, and their contents are emptied into shallow vats, 10–15 ft. across and 6–8 in. deep. Here the drug is worked up with the hands for 5–6 hours, until its colour and consistence are uniform, and its toughness enables it to be formed into balls of 8–10 oz. These, as formed, are thrown into a basket containing chaff of the seed-pods. They are then rolled in leaves and stalks of the poppy, left there for a week or so, and turned over occasionally till hard enough to bear packing. In October–November they are weighed, sent to market, and packed in chests, about 150 balls in each, the weight of each chest being as nearly as possible 1 *picul* (133⅓ lb.). The petals and leaves of the plant are used in packing the balls in the cases, but are not formed into "leaves" for enveloping the balls as in Bengal. The quality of Malwa opium is very uncertain, and much inferior to the Government-prepared article. The production is said to be about 20,000 chests annually.

The exportations of opium from India during the last quarter of a century, divided into quinquennial periods, have been as follows:—1854–5 to 1858–9, 74,239 chests annual average, 7,884,611*l.* average aggregate value (106*l.* a chest); 1859–60 to 1863–4, 68,119 chests, 10,608,648*l.* (156*l.* a chest); 1864–5 to 1868–9, 81,976 chests, 10,898,542*l.* (133*l.* a chest); 1869–70 to 1873–4, 87,840 chests, 11,722,111*l.* (133*l.* a chest); 1874–5 to 1878–9, 92,797 chests, 12,175,696*l.* (131*l.* a chest). The lowest aggregate value reached during this period was 6,200,871*l.* in 1855–6, the quantity being 70,626 chests. The highest aggregate was 13,365,228*l.* in 1871–2, being 93,364 chests. The figures for 1878–9 were 91,200 chests, 12,993,979*l.*, being a decrease caused by deficient crops in Malwa. The export trade is pretty equally divided between Bombay and Calcutta, and is mostly in Jews' hands in both places. The bulk goes to Hong Kong, and the largest proportion of the remainder to Singapore. The exports in 1880 were 144,638 cwt.; of this, 59,633 chests went to Hong Kong, 35,202 to the treaty ports, and 10,586 to Singapore.

In China.—The kind of poppy grown in China seems to be the same as that cultivated in Persia and India—*P. somniferum* var. *γ. album* (*P. officinale*). Though the production of Chinese opium is now considerable, and is, moreover, increasing in a very rapid manner, the chief interest concerning the drug in China has hitherto been centred upon its consumption. The inhabitants of that empire consume not only the whole quantity produced within their own boundaries, but are also customers for about 90 per cent. of the total Indian crop, besides drawing considerable supplies from Asia Minor and Persia. It is computed that 30 per cent. of the native male population throughout China are addicted to the use of the narcotic, and in the opium-producing districts, the proportion is increased to 50 per cent. Few moderate smokers consume more than 1½ lb. in a year, while occasional smokers do not take more than 1 oz. or so. The most immoderate scarcely require more than 4 lb., so that the approximate average all round may be taken at about ½ lb. a head for all classes of smokers. The native production is estimated at about 5,000,000 lb. annually, and the excess demand is supplied by importations of about 12,000,000 lb. This being so, the flourishing success of the opium industry in India, &c., may be said to depend absolutely upon the maintenance of the trade with China, and this again upon the conditions governing the extent to which the Chinese may or can become their own producers. This subject will receive attention presently. It will be convenient first to consider the modes of cultivating the poppy and preparing its narcotic, as practised by the Chinese, so far as they are known.

In the northern provinces, the cultivation of the poppy requires the richest soil and the utmost care. The plant can be successfully raised only on the terraced slopes, or on the most fertile bottom-land, which allows of thorough irrigation, and which is adapted for the cultivation of wheat and garden-stuffs. In the southern and central provinces, on the other hand, the soil is so rich and fertile that the most suitable lands for poppy-culture are the terraced hill-sides, where the effects of the heavy rains are less felt than in the lowlands. The seed is sown during November. The blossoms appear in April, and mature within a month, thus leaving the ground free for a summer crop. Before the poppies have seeded, an intermediate crop of wheat, maize, cotton or tobacco is put in, the poppy-stalks being cleared off in time to avoid interference with the up-coming shoots. The yield is very uncertain and quite dependent upon the weather, 1 *man* (say ⅙ acre) will give a value of 6–11 *taels* (of 5*s.* 10*d.*), according to the season, which is a much higher return than can be got from any other crop. For the collection of the opium, the heads are incised, much the same as in India, by a three-bladed lance, in a series of 3–5 vertical wounds, and the exuded juice is scraped off, and transferred to a small pot hanging at the waist. Of the subsequent manipulation for the market, little is known, beyond the fact that it is usually sun-dried to a certain consistence, and either mixed with the imported drug, or adulterated with liquorice, inspissated sesamum-juice, &c.; sometimes it undergoes both operations.

In entering upon a consideration of the circumstances surrounding the present and future prospects of the opium trade with China, the order most readily followed by the reader will perhaps be that of the Treaty Ports where the trade is carried on, commencing with the southernmost:—

(1) Kiungchow Foo, in the island of Hainan, province of Kwangtung.—The imports in 1876 were 520 *piculs* (of 133⅓ lb.), value 65,050*l.* In 1877, they were as follows:—Malwa, 320 *piculs*, 48,667*l.*; Patna, 388 *piculs*, 51,013*l.*; Benares, 16½ *piculs*, 2091*l.* And in 1878: Malwa, 242½ *piculs*, 42,795*l.*; Patna, 731 *piculs*, 95,985*l.*; Benares, 47 *piculs*, 6125*l.* In 1879, the imports were:—Malwa, 98¼ *piculs*, 18,409*l.*; Patna, 992½, 133,300*l.*; Benares, 27, 3114*l.*; total, 1117, 155,123*l.* The chief feature is the increase of Patna at the expense of Malwa, mainly due to difference in price. The Hainanese have not acquired a taste for Benares, which is used only by emigrants returning from the Straits Settlements. The increase observable in the figures quoted does not imply a greater consumption, but a larger proportion brought by steamer. The total importation from Hong Kong is estimated at 1200 *piculs* yearly for distribution over the north of the island and the southern coast of Leichow. The southern and eastern portions of the island draw their supplies from Singapore; the quantity cannot be estimated. As yet, no Yunnan, Kweichow, nor Szechuan opium has reached Hainan.

(2) Pakhoi, province of Kwangtung.—The only kind of Indian opium imported is Benares, of which the annual receipt is 300–400 chests. Native opium grown in the neighbouring (western) province of Yunnan is for sale, but is little used; its price is about ⅔–¾ that of Indian. Kwangse province, intervening, consumes very little Indian, drawing its principal supplies from Yunnan, and growing some itself. The flavour of the native drug has such a hold, that it will hardly be deserted for the dearer foreign article.

(3) Canton, province of Kwangtung.—The opium imported here in foreign vessels is very small, the needs of the city and district being supplied through Swatow, where the taxation is much less. The foreign imports in 1876 were:—Malwa, 239 *piculs*; Patna, 211 *piculs*; and in 1877, 121¾, and 202¼ respectively. During the past few years, the consumption of Yunnan, Kweichow, and Szechuan native opium has largely increased here. In 1878, the imports of Patna increased to 671½ *piculs*, mainly owing to the levying of a tax on all opium prepared in the prefecture of Kwangchow, and which is not expected to survive long. Still, in 1879, the imports of Patna increased to 1134¾ *piculs*, while Malwa fell to 58¾; the latter will probably soon disappear altogether from the Returns.

(4) Taiwan, island of Formosa, province of Fuhkeen (Fokien).—Opium is not grown, nor is Chinese opium much used here. The few lb. of the latter occasionally brought from Wenchow scarcely find purchasers. The imports and re-exports (in *piculs* of 133⅓ lb.) of foreign opium here for the years 1869–79 are shown (omitting fractions) in the annexed table:—

Years.	Imports.						Total Re-Exports.	Nett Total Imports.
	Benares.	Patna.	Persian.	Malwa.	Turkey.	Total.		
1869	1038	161	342	..	..	1541	8	1533
1870	1259	102	372	..	..	1733	2	1731
1871	1342	232	438	2	12	2026	53	1973
1872	1203	372	417	..	..	1993	52	1941
1873	1370	341	296	9	..	2016	64	1952
1874	1414	730	502	..	..	2645	142	2503
1875	1547	354	752	6	2	2661	61	2600
1876	1403	370	803	117	1	2693	35	2658
1877	1721	177	1325	9	2	3233	65	3168
1878	1480	38	1435	20	85	3059	206	2853
1879	1884	86	1331	71	138	3510	123	3387

The main features of this table are the enormous increase in Persian, and the decline in Malwa and Patna. The Persian is in great favour with the poor and hard-working colonists, and is largely imported for land transport to the north of the island, where the taxation is much heavier. Even Benares seems in danger of being driven out by Persian. Patna and Malwa will probably soon vanish from the returns, while Turkey shows a tendency to grow.

(5) Tamsui and Kelung, island of Formosa, province of Fuhkeen (Fokien).—The poppy is now grown near Oulan, on the seaboard to the south, and at two inland places, near the Tokoham river, within about 30 miles of Tamsui; the production is quite inconsiderable, and the consumption principally local. But there is a large consumption of native opium, grown partly in Szechuan and Yunnan, and partly in the neighbourhood of Ningpo and in the provinces of Chekiang and Fuhkeen. It would seem that the largest quantities come from Ningpo and Chinchew, the inland produce arriving entirely from the former. The proportion of this article as compared with foreign is said to be as 1 is to 5, so that the total imports of native opium in 1877 may have been 400 *piculs* (of 133⅓ lb.). There is thus a large (and increasing) consumption of the native drug; but its harshness, disagreeable flavour, and deficiency in strength cause its use alone (unmixed) to be confined to the poorest and lowest classes. The native article occurs in three qualities, two of which even the poorer people will not smoke unmixed. The proportions of admixture with Indian opium vary in different localities: at Bangka, and the larger towns on the W. side of the island, the usual ratio is 1 part native to 6 parts Indian; at Suao, and on the E. coast generally, half of each is adopted by the better classes, while for the lower classes, the proportion of native is probably greater. The annexed table shows the imports of foreign opium (in *piculs* of 133⅓ lb., neglecting fractions) in the years 1873–9:—

Description.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
Benares	1404	1260	1194	1440	1408	1398	1799
Malwa	3	..	..	9	1	..	..
Patna	109	286	105	115	72	25	25
Persian	191	158	271	284	455	514	314
Turkey	..	..	8	13	..	12	26
Total..	1708	1706	1579	1862	1937	1949	2164

From this, it will be seen that the consumption of foreign opium is increasing; at the same time, will be noticed the decrease in Indian, and rapid increase in Persian. This latter is largely used alone, and also in admixture with Indian, on the score of economy. It is not considered likely that Persian will ever supplant Indian entirely; but its consumption may be expected to increase in a higher ratio for some time to come.

(6) Amoy, province of Fuhkeen (Fokien).—The poppy is cultivated in the neighbourhood; but the production of native opium does not as yet seem to affect the foreign importations, as the imperfect system adopted in its preparation renders it far inferior in quality and flavour. The nearest native opium gardens are just outside the district city of Tung-ngan. The crop is sown yearly in December–January, and gathered in early April. The yield of the harvest gathered in 1879 was 221 *piculs*, which was all consumed in the vicinity, except some 10–20 *piculs* that reached Amoy without paying *li-kin*. In 1878, 1 *picul* of Szechuan opium, value 87*l.* was imported and re-exported. The imports and re-exports of foreign opiums in the same year, stated in *piculs* of 133⅓ lb. were as follows: Patna: imports, 2113¼; re-exports, 386½; Benares: imports, 3092½; re-exports, 1613; Malwa: imports, 1; Persian: imports, 965¾; re-exports, 636; Turkey: imports, 74¾; re-exports, 26; total: imports, 6247·15 *piculs*, value 957,285*l.*; re-exports, 2661·21 *piculs*, value, 276,819*l.* In 1879, the imports were:—Patna, 279,360 lb., 199,632*l.*; Benares, 608,480 lb., 422,751*l.*; Persian, 99,179 lb., 81,688*l.*; Turkey, 2993 lb., 2462*l.*; total, 990,012 lb., 706,033*l.* The re-exportation is almost entirely to Formosa, which trade is being gradually assumed by Hong Kong. The import trade is still chiefly in European hands, but is passing into Chinese.

(7) Foochow (Fuh-chow-Foo), province of Fuhkeen (Fokien).—The growth of the poppy is slowly but steadily increasing in the districts of Fuh-tsing, Fuh-ngan, and Tung-ngan. The production of opium is small as yet, and chiefly for local needs; in Fuh-tsing, it does not exceed 6 *piculs* (of 133⅓ lb.) yearly; in Fuh-ngan, about 10; and in Tung-ngan, 4. It is used in admixture with the stronger Indian drug, and its consumption is almost confined to the poorest classes. The native opium that finds its way into Foochow and the immediate neighbourhood comes from Wenchow and Tai-chow, in the adjoining province of Chekiang. The production there is said to amount to 2000 *piculs* yearly, but there is nothing to show what proportion reaches Foochow. The wealthier classes are likely to continue the use of the Indian drug, from force of habit, and preference for the superior article; but the native drug being much cheaper, easier to get, and less potent, will increase in favour with the remaining population. Hitherto, the commerce in Indian opium has not been seriously affected by the competition of the native product. The imports of Malwa were 2506 *piculs* in 1876, 1855⅓ in 1877, and 1479⅓ in 1878; of Patna, 1587½ in 1876, 1320½ in 1877, and 1725½ in 1878; of Benares, 141½ in 1876, 187¼ in 1877, and a little more in 1878. The import of Persian in 1878 showed an increase of 628 *piculs* over the figure for 1877. The figures for 1879 are:—Malwa, 1609½ *piculs*; Patna, 1768¾; Benares, 375½; Persian, 519. The native drug consumed was estimated at about 1000 *piculs*.

(8) Kewkeang (Kiukiang), province of Keangse.—A little native opium is produced in the centre of the province, about Kianfu, and is all consumed locally. The consumption of Szechuen native opium in this province seems to be limited to about a dozen chests annually. The annexed table shows the comparative imports (in *piculs* of 133⅓ lb.) of foreign opiums in the years 1868–78.

	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
Malwa ..	1910½	1895	2077½	2047½	1919¼	2349½	2889½	2231½	2037	1845	1475	1960
Patna ..	12	8½	6	8¼	13¼	16¾	15½	8½	4¾	4¾	8¼	6
Benares	1	2	27	8	2	..	..	6	1	1¼	..	..
Persian										1	170	204
Total	1923½	1905½	2110½	2063¾	1934½	2366¼	2905	2246	2042¾	1852	1653¼	2170

The diminution in total is due to the competition of neighbouring ports where the duties are less, rather than to reduced consumption in the province. The striking increase in Persian is ascribed to its low price.

(9) Wenchow, province of Chekeang.—Large districts are under poppy-culture in this province. The production of native opium in the Wenchow and Taichow prefectures in 1877–8 was:—Taichow prefecture, 1500 *piculs*; Wenchow prefecture: Yungchiachan, 600; Pingyang, 350; Yoching, 350; Hsichi, 400; Nanchi, 300; Massu, 700; grand total, 4200 *piculs*. In 1878–9, about 20 per cent. more land was planted, and the season was so favourable that the crop was expected to reach 8000 *piculs*. The native opium is used in and about the producing districts in an almost liquid state when exposed to the air; after keeping for a time, it dries up considerably, and loses as much as 35 per cent. by weight. It is said to possess little more than half the strength of Indian; but is more easily prepared, and much cheaper. Its liability to lose greatly in weight is likely to confine its use principally to the producing districts. Abundant crops and correspondingly low prices will

cause it to be largely consumed in admixture with Indian. The product supplies a great part of the adjoining province of Fuhkeen (Fokien), and is taken also to Formosa, Shanghai, &c. The direct importation of Indian opium here is much crippled by the competition of Ningpo and Shanghai. In 1878, it amounted to 3 *piculs* of Malwa and 11 of Patna; yet the consumption in the town alone was 50 chests Malwa, and 90 chests Patna. In 1879, the recorded imports of Patna were 57½ *piculs*.

(10) Ningpo, province of Chekeang.—The native drug from the Wenchow and Taichow prefectures is brought to this city in a fluid state, in small earthen jars containing 2–4 lb., and a market for its sale is held at stated periods at one of the city gates. The export through this city of native opium produced in those portions of the provinces of Anhui (Gan-hwuy) and Kiangsu north of the Yangtse-kiang, is on the increase. In 1879, some 300,000–400,000 lb. of native opium came on the market, but this is probably less than half the total product of the province. Indian opium will always be preferred by those who can afford it; but Persian and other cheaper kinds are expected to almost monopolize the market in the near future, unless the prices of Indian are much reduced. The nett imports of foreign opiums (in *piculs* of 133⅓ lb.) in 1877, 1878, and 1879 respectively, were as follows:—Malwa, 7642, 6518, 6768; Patna, 204, 400, 486; Benares, 183, 170, 302; Persian, 30, 163, 94.

(11) Hankow, province of Hoopih (Hupeh).—Native opium is largely used in this province. It comes chiefly from Szechuen, but the Yunnan article is considered superior. The dealers from Shansi province visiting Hankow smoke Yunnan opium, and take it home with them, as in Shansi and Kansuh provinces poppy-culture is now prohibited. The quantities (in *piculs* of 133⅓ lb.) of the native product (*a*) imported and (*b*) re-exported, on which taxes were paid, were as follows:—1875, *a* 1600¼, *b* 893½; 1876, *a* 2888, *b* 1696½; 1877, *a* 1684½, *b* 1108; 1878, *a* 2531, *b* 881. The imports of foreign opiums (*a*, Malwa; *b*, Patna and other kinds), in *piculs* of 133⅓ lb. for a series of years have been as follows:—1867, *a* 4072, *b* 169; 1868, *a* 2770, *b* 99; 1869, *a* 3415, *b* 193; 1870, *a* 3473, *b* 206; 1871, *a* 2988, *b* 156; 1872; *a* 2285, *b* 115; 1873, *a* 2811, *b* 162; 1874, *a* 2717, *b* 133; 1875, *a* 2160 *b* 158; 1876, *a* 2017, *b* 172; 1877, *a* 2274, *b* 201; 1878, *a* 1905, *b* 218½. In 1879, the imports of foreign were:—Malwa, 2678½ *piculs*, 403,534*l.*; Patna, 579¼, 66,611*l.*; Persian, 36, 3281*l.* The exports of native were 120 *piculs*, 6528*l.*

(12) Ichang, province of Hoopih (Hupeh).—The poppy is cultivated in this province, and a district called Chiao-t'u has a local reputation for its opium, to which it gives its name; but the chief consumption is of the Yunnan drug. Nevertheless, native officials admit that 2000 *piculs* are produced annually in the province, chiefly in the hilly country about Patung. Foreign opium is yet scarcely known, and does not figure at all in the official Returns, though it is occasionally smuggled.

(13) Shanghai, province of Kiangsu (Keangsoo).—In 1877, the local consumption of native Szechuen opium was estimated at above 200 *piculs* a month; in 1878, not more than 20 *piculs* monthly were imported. The yield of the Szechuen crop in 1878 was placed at 50,000 *piculs*, and of the Yunnan at 15,000. Formerly, the northern province of Shensi (Shanse) was reckoned to afford 30 per cent. of the total native product, but since the famine, poppy-cultivation has been somewhat rigidly prohibited in Shensi, Honan, and Chihli. The Shensi drug was esteemed the best, having a flavour resembling Patna, and giving 85–90 per cent. on boiling. Yunnan is classed second, and Szechuen third. It is broadly estimated that about half the Yunnan product is consumed locally, and that the other half is exported to and through the adjacent provinces of Kwangtung, Kwangse, and Kweichow. Of the Szechuen crop, about 25 per cent. is kept for local consumption, 40 per cent. goes to the northern provinces, and 35 per cent. is disposed of to the provinces watered by the Yeangtse-kiang. The imports of native opium into Shanghai in 1878 were 798 *piculs* of Szechuen, and 0·69 *piculs* of "prepared." The re-exports were 35¾ *piculs* of "husk" (to Chinese ports), 65 *piculs* of Szechuen (total), and 1½ *piculs* "prepared" (to Chinese ports).

The commerce in foreign opiums at this port in the years 1878 and 1879 is shown in the annexed tables. The imports (in *piculs* of 133⅓ lb.) were as follows:—

	From foreign countries.		From Hong Kong and Chinese ports.		Total nett after deducting re-exports.	
	1878.	1879.	1878.	1879.	1878.	1879.
Malwa	28,020	32,500	875	1,453½	1,803	1,794
Patna	10,208½	12,174½	63½	107	8,525	9,454¾
Benares	6,435½	7,633¼	62½	5	5,157½	5,572¾
Persian	1,679½	2,321¼	267	221	178⅓	218¾
Turkey	21¼	..	1	..	21	..

The re-exports and their destinations in 1878 were as follows:—

	Newhcwang.	Tientsin.	Chefoo.	Hankow.	Kewkeang.	Wuhu.	Chinkiang.	Ningpo.	Wenchow.	Foochow.	Hong Kong.	Total.
Malwa	783	3381½	3456½	1833	1594	2279½	8768½	4723½	11	241½	20	27,092
Patna	54	225½	44½	224½	8½	3½	747½	400¾	8½	30	..	1,747¼
Benares ..	36	34¾	140½	1½	..	..	936	192	..	..	..	1,340¾
Persian	53	397	111	33	177	53	664	190½	..	5	76¾	1,760¼
Turkey	..	..	..	..	..	..	..	1	..	..	¼	1¼

There was a further re-exportation of 8 *piculs* of Persian to London. The Persian opium in the Shanghai market is competing most successfully with Indian, not for local consumption, but for re-export chiefly to Chinkiang and Tientsin. In consistence and flavour, it much resembles Malwa. The parcels of it imported in 1877 were adulterated with sugar, &c., and of irregular shape; but in 1878, a marked improvement took place both in manipulation and purity. The imports of native opium in 1879 were 117½ *piculs* of Szechuen, and 1½ of prepared.

(14) Chinkiang, province of Kiangsu (Keangsoo).—This port ranks next to Shanghai in the importance of its opium-trade, and takes about $\frac{1}{7}$ of the whole foreign opium sent to China. The imports of native opium here were 48 *piculs* in 1877, and 76 in 1878. In the latter year, the price advanced, in consequence of poppy-culture being prohibited in Hsuchow, and other places. The importations of foreign opiums (in *piculs* of 133⅓ lb.) in 1877, 1878, and 1879 respectively, were as follows:—Malwa, 9782, 8639, 8144; Patna, 506, 737, 875; Benares, 479, 936, 1357; Persian, 32, 645, 721; totals, 10,709, 10,957, 11,097. The totals for the three previous years were 10,964, 11,758, and 10,649. Malwa is rapidly giving way to Persian, the latter being so much cheaper—25–40 per cent. The native opium imported through the foreign custom-house in 1879 amounted to 19 *piculs.*

(15) Chefoo, province of Shantung.—The poppy is cultivated in the Tsaochow department; but the yield of opium is small, and none seems to be exported. The trade in foreign opiums at this port is much influenced by the native crops in the provinces of Shensi and Shingking (Liaotung). The culture of the poppy is prohibited here, but in regard to the latter, the prohibition has always been a dead letter. In Shensi, it has been at least partially enforced since the famines, and considerably lessened production in Shantung, Shensi, and Honan provinces may be expected for some years to come. The competition of the native article caused a decrease in the importations of foreign from 565,137 lb. in 1872, to 326,037 lb. in 1877. In 1878, the native Shingking (Liaotung) crop failed, and this, combined with the partial enforcement of the prohibition in Shensi, caused a great recovery in the foreign trade, the imports for that year reaching 505,618 lb. In 1879, the prohibitions against native opium-growing were more rigidly enforced, yet the consumption of foreign suffered a decline; the total foreign nett import was 471,566 lb., contributed thus—Malwa, 2996½ *piculs*; Patna, 50½; Benares, 330½; Persian, 159. The great increase in Persian is the most notable feature.

(16) Tientsin, province of Chihli.—The trade here is similarly affected by the native production. The Peking consumption consists of about $\frac{7}{10}$ Malwa, and $\frac{3}{10}$ native, the latter chiefly from Honan, Szechuen and Yunnan provinces. Honan, in 1877, only yielded about 30 per cent. of this, while in 1876, its production was 50 per cent., and the price was about 25 per cent. less. The nett import of Malwa opium in 1877 was 3769 *piculs*, and Bengal and other varieties brought the total of foreign to 4034 *piculs*, showing an increase on the previous year of 323 *piculs* in Malwa, 14 in Benares, and 37 in Persian. This rise was due to exceptional circumstances, and the figures cannot be maintained when Honan resumes the culture. Peking alone consumed 1800 *piculs* of Indian opium in 1877, one-third of which was smuggled in. The duties on foreign brands are just about double those on native. The nett imports of foreign in 1878 and 1879 respectively (in *piculs*) were:—Malwa, 3530½, 4189½; Patna, 164¼, 373¼; Benares, 21½, 66; Persian, 291, 553. In addition, 280 of Malwa, 6 of Patna, and 61 of Persian, were re-exported. The growth in Persian is remarkable; it is almost entirely used for adulterating Malwa, being mixed with it to the extent of 30 per cent.

(17) Newchwang, province of Shingking (Liaotung).—The production of native opium in many of the districts northward and eastward of this port is rapidly increasing. In the immediate neighbourhood of Newchwang, and from Naichow all round the coast, the poppy is grown only in gardens, and for domestic use. The soil is stony and unsuited, and the greater part of the native opium there consumed is brought from inland districts. But the culture is so general in most parts of the province of Fengtien, that it is said to occupy 80 per cent. of the total agricultural area. In many parts of the provinces of Kirin (Girin) and Tsitsikhar (Tsi-Tsi-Har), in E. Mongolia, notably and

for a long time past in the district lying on the right bank of the Sungari, in the angle formed by the reaches of that river, above and below its junction with the Nonni, E. and S.-E. of Petuna (Bodune), a daily increasing production is taking place. In Russian Mandchuria, in the strip of country lying on the sea-board between the Amur and Corea, the poppy is not grown, and no opium is admitted into that territory. The large and increasing production in the districts named, whither numbers of Chinese colonists had emigrated with the sole object of poppy-growing, the industry there being altogether free and untaxed, was gradually driving all foreign competitors out of the markets of N. China; but in 1879, official prohibitions were so rigorously enforced in Kirin and Fengtien, that the crop was only ⅕ of the average. The imports, in *piculs* of 133⅓ lb., in the four years 1876–9 respectively, were:—Malwa, 2236, 988, 1112, 2141; Patna, 28, 36, 57, 98; Benares, 37, 43, 27, 62; Persian, 2, 31, 25, 151.

There are now two other treaty ports to be taken into account, viz. (18) Wuhu, province of Anhui, and (19) Macao, province of Kwangtung. The imports of foreign opium at the former in 1877, 1878, and 1879 respectively, stated in *piculs*, were:—Malwa, 1157, 2324½, 3036½; Patna, 2½, 2½, 9½; Benares, nil, nil, 2½; Persian, 2, 54, 92½. Almost half the total is consumed in the city itself. No native drug seems to be imported, the Indian being adulterated with Persian. Macao imported 5000 chests of crude Patna in 1878; in 1879, a factory was started for preparing the drug for export to California and Australia, and the future imports will probably increase immensely.

From a review of the foregoing details, it seems that certain Chinese provinces, notably Szechuen, Kweichow, and Yunnan, are serious competitors in the production of opium, while Shensi, Shantung, and N.-E. Mandchuria are rapidly becoming formidable. On the other hand, the increase must be determined by the area of land which can be spared from food-crops for the purpose, and this, judging by the recent famines, cannot be indefinitely great. Moreover, the superiority of the foreign drug is everywhere acknowledged, price being the only bar to its very much wider use. The consumption of the various kinds is curiously marked by distinct zones. Thus along the coast, as far north as the Yangtze-kiang, excluding the neighbourhood of Ningpo, Bengal is chiefly in favour, mostly Patna, but Benares in Fokien and Formosa; to the north and west, including part of Kwangtung, Kwangse, Kiangsi, Anhui, the N.-E. provinces, and Shingking, Malwa is consumed to the almost total exclusion of Bengal; whilst northward and westward again of this line, the native article stands first. Each kind of opium has special characteristics, which commend it to the natives of certain districts. The Bengal drug—Patna and Benares—is considered mild, is well prepared and genuine, is preferred by all refined smokers, and is apparently best suited to the relaxing climate of the southern portions of the empire. Those accustomed to it will not exchange it for other kinds unless compelled to do so; but they will mix inferior sorts with it to reduce the nett cost. Malwa is esteemed strong, fiery, and irritating to the nervous system, being a much cruder drug, yet far inferior to the best native; it is being largely replaced by the local product. This last, the native article, has all the bad qualities of Malwa intensified. The harshness is appreciated by the natives of the colder districts, and in those parts where the Tartar element predominates. As the taste becomes educated, preference is manifested for the superior article; and there is no doubt that, by judicious regulation of the prices, Indian producers can always command a very large market.

In Egypt.—The variety of poppy grown in Egypt is the same as that cultivated in Asia Minor. The production of opium is said to be in the hands of the Government, and to be restricted to the actual requirements of the sanitary establishments. On the other hand, it is openly exported. The cultivation is carried on in Upper Egypt, near Esneh, Kenneh, and Siout, where about 10,000 acres were said to be occupied by it in 1863. The capsules are incised in March, by drawing a knife twice round them transversely; the concreted juice is scraped off next day by a scoop-knife, collected on a leaf, and placed in the sun to harden. With due care, the product is of sufficiently good quality, containing 10–12 per cent. of morphine; but the plants are usually grown in too moist soil, and the scarification is often prematurely performed, and these circumstances combine with wilful adulteration to reduce the morphine to 3–4 per cent. on the average. The drug occurs in European commerce in the form of hard, flattish cakes, about 4 in. in diameter, covered with fragments of poppy leaf, but free from *Rumex* chaff. The fractured surface is finely porous, and dark liver-coloured, and reveals shiny imbedded particles and reddish-yellow points, besides occasional starch granules. In 1872, the United Kingdom imported 9636 lb., value 5023*l.*, of opium from Egypt; in 1879, the values of the total Egyptian exports were—to Italy, 990*l.*; France, 630*l.*; Greece, 540*l.*; Turkey, 150*l.*; total, 2310*l.*

Preparation and Use.—As a narcotic, opium is used one of three ways:—(1) Swallowed in the form of pills, or (2) as a fluid tincture; (3) smoked in pipes. The first practice prevails mostly in Asia Minor and Persia, the second is that usually adopted by Christians who become addicted to it, the third is general among the Chinese, Malays, &c., who consume about $\frac{9}{10}$ of the whole world's production. The Chinese, before smoking the opium, subject it to a process of extraction in water. This is largely done in Hong Kong and in the opium-vessels. The Bengal opium as received is removed from the outer covering of poppy-trash, &c., moistened, and allowed to stand for about 14 hours. It is then placed in shallow pans made of some copper alloy, built into furnaces, and heated by charcoal fires; 2½ cakes of opium and 10 pints of water go into each pan, being boiled and occasionally stirred till a uniform thin paste is produced, occupying 5–6 hours. This paste is transferred to a larger pan, and the bulk is made up to 3 gal. by adding cold water; it is covered, and left for 14–15 hours. A bunch of vegetable pith used for lamp-wick is then inserted into the mass, the pan is tipped, and a rich, clear, brown fluid is drawn off and filtered through bamboo paper. The residue is put on a calico filter, and thoroughly washed with boiling water, the wash-water being reboiled and repeatedly used. The last washing is done with pure water, and all the washings are used for the next day's boiling. The residues are transferred from the calico filters to a larger one, and are well pressed; the insoluble residue, called *nai chai* ("opium dirt"), is mostly sent to Canton, where it is used in the manufacture of inferior "prepared" opium. The filtrate or opium solution is evaporated at the boiling point, with occasional stirring, till of the proper consistence, requiring 3–4 hours. It is then removed from the fire, and stirred vigorously till cold, the cooling being hastened by fanning; when cold, it has the consistence of thin treacly extract, and is known as "prepared" or "boiled" opium. It is kept for some months before acquiring prime condition, and is then sent out sealed up in small pots.

The Chinese recognise four grades of opium:—(1) The "raw" as imported; (2) "prepared," as just described; (3) "dirt," the insoluble residue after exhaustion in water; (4) "dross," the scrapings from the pipe, being the unconsumed ash, which is re-manufactured as a second-class "prepared" opium, being about 50 per cent. of the amount placed in the pipe for smoking. In China, the pipe is prepared by placing a little pill of the drug upon a needle, so that it rests exactly over the central hole in the pipe-bowl; a lamp is then applied to ignite it, and the vapours are drawn deeply into the chest, and slowly exhaled through the nose and ears. In Borneo, Java, and Sumatra, the liquid extract is mixed with finely chopped tobacco and betel-nut till absorbed, and pills of this are placed in the pipe.

Nature and Properties.—Opium contains no less than 17 distinct alkaloids, in very variable proportions, but two only are of importance in determining its value as a narcotic: these are morphine ($C_{17} H_{19} NO_3$), the more valuable; and narcotine ($C_{22} H_{23} NO_7$). Of European opiums, some French samples have given 22·88, 21·23, 20·67, 17·6, 17·5 and 14·96 per cent. of morphine respectively; German specimens afforded 20, 12–15 (Würtemberg) and 9–10 per cent. (Silesia). A pure American opium, from Vermont State, showed 15·75 per cent. of morphine, and 2 per cent. of narcotine. The Asia Minor article resembles the European: the maximum recorded is 21·46 per cent., while the mean of 8 samples was 14·78, and of 12 others, 14·66 per cent.; from several cases of Smyrna opium, 12–13 per cent. of pure morphine was got from the fresh, moist drug; and of 92 other specimens, one half yielded over 10 per cent., and the richest was 17·2 per cent. Thus it may be assumed that good Turkey opium dried at 100° (212° F.) should give 12–15 per cent. of morphine, and that less than 10 may indicate adulteration. The Persian drug is extremely unequal from adulteration, but sometimes very good; four samples have given 13·47, 11·52, 10·12, and 10·08 per cent. of morphine; and other samples undried, 8–10·75 per cent. The Indian opiums are remarkable for their low percentage of morphine, due probably to the long period during which the juice is kept in a moist state, not less than to climatic influences. Samples of Benares opium gave only 2·48, 2·38, 2·20, and 3·21 per cent. of morphine. Khandesh specimens showed 6·07 and 7 per cent. Patna garden opium, prepared exclusively for medicinal use, afforded 8·6 per cent. of morphine and 4 per cent. of narcotine, while another sample gave 7·72 per cent. of morphine. Various other samples of Indian opiums yielded the following percentages of morphine:—Medical, 4·3; Behar garden, 4·6; Abkari, 3·5; Sind, 3·8; Hyderabad, 3·2 (and 5·4 narcotine); Malwa, 6·1. Chinese native opiums are as a rule about the same, thus:—Szechuen, 2·2; Kweichow, 2·5; Yunnan, 4·1; Kansu, 5·1; another Szechuen sample, 3·3; and another from Kweichow, 6·1; whilst one Chinese specimen, undried, afforded 5·9 per cent. of morphine, and 7·5 of narcotine. A sample of Egyptian opium yielded 5·8 per cent. of morphine and 8·7 of narcotine. The proportions of narcotine in opiums differ quite as much. A German sample gave 10·9 per cent.; some Turkish and Persian specimens varied from 1·3 to 9·9 per cent. The Khandesh (Indian) opium previously mentioned gave 7·7 per cent.; and E. Indian Government opium frequently contains twice as much narcotine as morphine. In the practical estimation of the value of an opium, by the British pharmacist, the only conditions considered are the percentages of water and of morphine. (See Alkalies [Organic]—Morphine, p. 231).

The value of opium in medicine is unquestioned. With regard to its use as a narcotic, great efforts have been made by a few well-intentioned but ignorant people to procure its annihilation. But though the abuse of the drug leads to evil consequences—by no means equalling, however, those of the abuse of alcohol in this country—its moderate use is extremely beneficial, if not absolutely necessary, in the malarial climate of China, where almost the whole is consumed, and the immunity of opium-smokers from diseases of the bronchial tubes and lungs, so common among non-smokers, is remarkable. The real remedy for excessive opium-smoking in China lies in the development of the resources of the country, enabling the inhabitants to occupy healthy houses and consume wholesome food; the abuse of opium would then die out of China, as the abuse of laudanum died out of Lincolnshire after the fens were drained. An antidote for opium-smoking is the use of coca (see p. 1307).

Imports and Values.—The importations of opium into the United Kingdom were 41,000 lb. in 1839, 114,000 lb. in 1852, and 400,303 lb. in 1876. The supplies of 1876 were contributed as follows:—315,624 lb. from Turkey, 51,165 lb. from Persia, 13,390 lb. from British India, 5660 lb. from China, and 14,464 lb. from other countries. The imports in 1879 were:—499,351 lb., 396,123*l.*, from Turkey; 47,240 lb., 19,977*l.*, from Persia; and 25,820 lb., 16,610*l.* from other countries; total, 572,411 lb., 432,710*l.* Of our colonies, it may be mentioned that Victoria imported prepared opium to the value of 104,557*l.* in 1876, doubtless for the use of the Chinese labourers engaged on the gold-fields.

The approximate value of "fine" Turkey opium in the London market is 15–25*s.* a lb.; "other qualities," 12–21*s.* a lb.

Pituri.—The substance known as *pituri* among the Australian aboriginals, and popularly spelt *pitcheri*, *pitchoury*, *bedgery*, &c., by Europeans, has recently attracted considerable attention. The results of investigations indicate the source of the narcotic to be the leaves of *Duboisia Hopwoodii.* This shrub extends from the Darling River and Barcoo, throughout Queensland, S. Australia, and the desert scrubs of Central Australia to W. Australia, and seems to be more plentiful than was at first supposed. The shrub is of bushy growth, with dark, thick, glossy foliage, and reaches a height of 8–9 ft. It is most commonly found on sandy spinifex flats, in well-watered country. Sylvester Brown indicates a locality of some 400 sq. miles, just on the S. Australian border, about 23° S. lat., as an admirable spot for a reserve of the plant, which grows there abundantly. The native blacks gather the leaves annually during the month of August, when the plant is in blossom, and hang them up to dry. They are sometimes sweated beneath a layer of fine sand, dried, roughly powdered up, and then packed in netted bags, skins, &c., for purposes of transport. To prepare them for use, they are damped, mixed with potash obtained from suitable plants, and rolled up into the shape of a cigar. This is chewed, and the saliva is swallowed. In small quantities, it has a powerful stimulating effect, assuaging hunger, and enabling long journeys to be made without fatigue, and with little food. In large doses, it is maddening. The narcotic principle has been separated in the form of an alkaloid, termed "piturine," prepared in the same manner as nicotine, which it closely resembles, if it be not actually identical. The leaves are an important article of inter-tribal commerce. In native use, it takes the place of the coca (p. 1307) of S. America, the ava (p. 1305) of Fiji, and the tea of China. It is suspected that *D. myoporoides*, extending on forest land from near Sydney to near Cape York, and traced also in New Guinea, shares the properties of the first species, as an alkaloid termed "duboisine" prepared from it seems to be identical with piturine. Several species of the allied genus *Anthocercis*, found throughout the greater part of the Australian continent and in Tasmania, also deserve investigation, as *A. viscoso* is known to possess the property of contracting the pupil of the eye. (See Drugs—Duboisia, p. 810).

Rhododendron.—The rhododendrons possess considerable narcotic virtues. The flowers of *Rhododendron arboreum* are eaten as a narcotic by the hill-people of India, and a snuff is made from the bark. The leaves of *R. campanulatum* are used as snuff by the natives of India, and the brown dust which adheres to the petioles is used for a similar purpose in N. America. *R. chrysanthemum* in Siberia is one of the most active of narcotics.

Siberian or Intoxicating Fungus.—The poisonous toad-stool, *Amanita muscaria* [*Agaricus muscarius*], is the narcotic of Siberia. It closely resembles some of the edible mushrooms, and is common in fir-, beech-, and birch-woods in N. England. It grows very abundantly in parts of Kamtschatka, where it is either collected during the hot months, and hung up to dry in the air, or is left in the ground to ripen and dry, and is afterwards gathered. It is more narcotic in the latter case. The most common way of using it is to roll it up like a pill, and swallow it without chewing. If steeped in whortleberry-juice, and other vegetable juices, it imparts strong intoxicating qualities. Eaten fresh in soups, &c., it is less powerful. One or two suffice to produce pleasant intoxication for a whole day. It provokes remarkable activity, stimulates bodily exertion, and induces violent exhibitions of passion. A singular feature of it is that the active principle passes unimpaired into the urine, and remains for a long time; this fact is well known to the Siberians, and is availed of by them in a most abominable manner. It is a significant fact that the exports of this fungus from Archangel in 1878 were:—230 *poods*, value 4200 *roubles*, to Great Britain; 25 *poods*, 375 *roubles*, to Holland; and 115 *poods*, 1725 *roubles* to France; the total amounting to 7 tons, value 630*l.*

Syrian or Steppe Rue.—The seeds of *Peganum Harmala*, a plant abundant in the Crimea, are occasionally eaten by the Turks as a narcotic indulgence. The active virtues seem to reside in the husk of the seed, which contains about 4 per cent. of two alkaloids, called harmine ($C_{13}H_{12}N_2O$) and harmaline ($C_{13}H_{14}N_2O$).

Thorn-apples.—The fruit of the red thorn-apple of Peru (*Datura sanguinea*), which grows on the less steep slopes of the Andean valleys, is used by some tribes of the Indians for preparing a strong narcotic drink, called *tonga.* The whole plant is narcotic, but the seeds are most powerful. The seeds of the common thorn-apple, *D. Stramonium,* possess similar properties. They are used as poison on the Continent and in India; and in Russia, China, and Upper India, they, or the seeds of other species (*D. Melet*, *D. fastuosa*, *D. alba*), are employed to increase the intoxicating qualities of fermented liquors. The dried leaves of *D. Stramonium* and *D. tatula,* made into cigarettes, are smoked as a cure for some forms of asthma (see Drugs—Stramonium, p. 826).

Tobacco.—Tobacco, the most largely and widely consumed of all narcotics, is the product of a number of plants belonging to the genus *Nicotiana.* The species and varieties having most interest for the cultivator are the following:—

I. *N. Tabacum macrophylla* [*latifolia, lattissima, gigantea*]—Maryland tobacco. Of this, there are two sub-species—(1) Stalkless Maryland, of the following varieties: (*a*) *N. macrophylla ovata*—short-leaved Maryland, producing a good smoking tobacco, (*b*) *N. macrophylla longifolia*—long-leaved Maryland, yielding a good smoking tobacco, and excellent wrappers for cigars, (*c*) *N. macrophylla pandurata*—broad-leaved, or Amersfort, much cultivated in Germany and Holland, a heavy cropper, and especially adapted for the manufacture of good snuff; (2) Stalked Maryland, of the following varieties: (*a*) *N. macrophylla alata,* (*b*) *N. macrophylla cordata*—heart-shaped Maryland, producing a very fine leaf, from which probably the finest Turkish is obtained. Cuban and Manilla are now attributed to this group.

II. *N. Tabacum angustifolia*—Virginian tobacco. Of this, there are two sub-species—(1) Stalkless Virginian, of the following varieties: (*a*) *N. angustifolia acuminata,* grown in Germany for snuff, seldom for smoking, (*b*) *N. angustifolia lanceolata,* affords snuff, (*c*) *N. angustifolia pendulifolia,* another snuff tobacco, (*d*) *N. angustifolia latifolia*—broad-leaved Virginian, used chiefly for snuff, (*e*) *N. angustifolia undulata*—wave-like Virginian, matures quickly, (*f*) *N. angustifolia pandurata,* furnishes good leaves for smoking, produces heavily, and is much grown in Germany, and said to be grown at the Pruth as "tempyki," and highly esteemed there; (2) Stalked Virginian, of the following varieties: (*a*) *N. angustifolia alata,* (*b*) *N. angustifolia lanceolata* [*N. fructiosa*], growing to a height of 8 ft., (*c*) *N. angustifolia oblonga,* (*d*) *N. angustifolia cordata*—E. Indian, producing heavily in good soil, and well adapted for snuff, but not for smoking. Latakia and Turkish are now accredited to *N. Tabacum.*

III. *N. rustica*—Common, Hungarian, or Turkish tobacco. Of this, there are two varieties: (*a*) *N. rustica cordata*—large-leaved Hungarian, Brazilian, Turkish, Asiatic, furnishing leaves for smoking; (*b*) *N. rustica ovata*—small-leaved Hungarian, affords fine aromatic leaves for smoking, but the yield is small. Until quite recently, Latakia, Turkish, and Manilla tobaccos were referred to this species; Latakia is now proved to belong to *N. Tabacum,* and Manilla is said to be absolutely identical with Cuban, which latter is now ascribed to *N. Tabacum macrophylla.*

IV. *N. crispa*—This species is much grown in Syria, Calabria, and Central Asia, and furnishes leaves for the celebrated cigars of the Levant.

V. *N. persica.*—Hitherto supposed to be a distinct species, affording the Shiraz tobacco, but now proved to be only a form of *N. Tabacum.*

VI. *N. repanda.*—A Mexican plant, with small foliage. Long thought to be a distinct species peculiar to Cuba, but none such is now to be found in Cuba, whether wild or cultivated, and all the Cuban tobacco is now obtained from *N. Tabacum macrophyllum.*

Among the many other forms interesting only to the botanist or horticulturist, the principal are *N. paniculata*, *N. glutinosa*, *N. glauca*, attaining a height of 18 ft., and *N. clevelandii*, exceedingly strong, quite recently discovered in California, and supposed to have been used by the early natives of that country.

Cultivation and Curing.—The following observations on the methods of cultivating and curing tobacco have reference more particularly to the processes as conducted in India and the United States; this branch of agriculture has been brought to great perfection in the latter, and the supervision of the operations in India is mostly entrusted to skilled Americans.

Climate.—Of the many conditions affecting the quality of tobacco, the most important is climate. The other conditions that must be fulfilled in order to succeed in the cultivation of this crop may be modified, or even sometimes created, to suit the purpose; but cultivators can do little with reference to climate: the utmost they can do is to change the cultivating season, and this only in places where tobacco can be grown nearly throughout the year. The aromatic principles, on the presence of which the value of a tobacco chiefly depends, can only be properly developed in the plant by the agency of high temperature and moisture. The fame that Cuban and Manilla tobaccos enjoy is mostly due to the climate. The article produced in Cuba is most highly esteemed; up to this time, no other country has been able to compete successfully with it. However it cannot be doubted that there are many places whose climate justifies the assumption that a tobacco could be grown there, not inferior to that produced in the W. Indies. The more closely the climate of a place corresponds with that of Cuba, the greater chance is there that a Havanna variety will preserve its peculiar aroma. In such places, a fine and valuable tobacco may be grown with less expenditure on labour, &c., than it is necessary to bestow in raising an inferior article in less suitable climes. In countries where a low temperature rules, the plants must be raised in hot-beds, and there is also a great risk that the young plants may be destroyed by frost, or afterwards by hailstones. When damp weather prevails during the tobacco harvest, it is often injured; and to give the required flavour, &c., to make the article marketable, macerating has often to be resorted to, thus involving great risk and expenditure. But in spite of these drawbacks, tobacco cultivation is often very remuneratively carried out in countries possessing an unfavourable climate. The deficient climatic conditions are here partly compensated for by making the other conditions affecting the quality of tobacco, and which can be controlled by the cultivator, the most favourable possible.

Soil.—The soil affects to a great extent the quality of a tobacco. The plant thrives best in a soil rich in vegetable mould; this, however, is not so much required to supply the necessary plant food, as to keep the soil in a good physical condition. No other plant requires the soil in such a friable state. A light soil, sand or sandy loam, containing an average amount of organic matter, and well drained, is considered best adapted for raising smoking-tobacco; such a soil produces the finest leaves. The more organic matter a soil contains, the heavier is the outturn; but the leaves grow thicker, and the aroma becomes less. As, in tropical climates, the physical properties of the soil play a prominent part in its productive capabilities generally, and the presence of organic matter in the soil tends to improve these properties, it will rarely occur that in such places a soil will contain too much humus. The more clay in a soil, the less is it adapted to the production of fine smoking-tobacco, on account of its physical properties being less favourable to the development of the aromatic principles; the leaf becomes also generally thick and coarse, but the outturn on such soils is generally heavier than on a more sandy one. A clay soil possessing a great amount of humus may, if properly tilled, produce an ordinary smoking-tobacco, and may even, if great attention be paid to the selection of the variety, &c., produce leaves for cigar-wrappers.

Of less importance than the physical properties of the soil is its chemical composition. By proper tillage and heavy manuring, tobacco is sometimes grown on comparatively poor soils. From analysis of the plant, it is clear that it contains a large amount of ash constituents, which it extracts from the soil; the most important of these are potash and lime. A soil destitute of these constituents would require a great quantity of manure to supply the wants of tobacco.

Situation.—Land intended for tobacco-culture should have good drainage, and be sheltered from high winds. In Holland, where tobacco-cultivation is carried out to great perfection, each field is surrounded by a hedge about 7 ft. high; the fields are divided into small plots, which are again bordered by rows of plants that are able to break the force of the wind, which would injure the leaves, and render them of comparatively little value. To this circumstance, must chiefly be attributed the fact that Dutch growers succeed in getting as much as 50 per cent. of leaves of the first quality, whereas in most other countries 25 per cent. is considered to be a very good outturn.

Manure.—In its natural state, the soil will rarely possess the elements of plant food in such a form as is most conducive to the production of a fine tobacco-leaf. Any deficiency must be supplied in the shape of suitable manure. Schlösing found that a bad burning tobacco was produced on a soil containing little potash, on unmanured soil, on soil manured with flesh, humus, calcium chloride, magnesium chloride, and potassium chloride. A good burning tobacco was produced on a soil manured with potassium carbonate, saltpetre, and potassium sulphate. More recent experiments carried out by other investigators tend to corroborate these conclusions. It is generally assumed that a soil rich in nitrogenous organic matter produces a strong tobacco that burns badly.

The results of Nessler's experiments clearly show that it is not sufficient to apply the element most needed by the plant—potash—in any form, but that, to produce a good tobacco, it is necessary to apply it in a particular combination. It was found that carbonate of potash applied as manure produced the best tobacco: it burnt for the longest time, and its ash contained most carbonate of potash; whereas chloride of potash produced a much inferior tobacco. The assertion of other experimenters that chlorides produce a bad tobacco is thus confirmed. Sulphate of potash and sulphate of lime produced a good tobacco. It may be noticed here that tobacco which was manured with gypsum contained a great amount of carbonate of potash in the ash, probably due to the fact that gypsum is a solvent for the inert potash salts. From the foregoing, it may be concluded that in tobacco cultivation, the elements potassium and calcium should be restored to the soil in the form of carbonate, sulphate, or nitrate, but not as chlorides. Poudrette, or prepared night-soil, generally contains a considerable amount of chlorides, and is not well suited as manure for fine tobacco. It has been found that fields manured with chlorides produced heavily; a small proportion of chlorides may therefore be applied in this form, whenever quality is of less importance than quantity. Farmyard manure may suffice when tobacco is cultivated in proper rotation, but here also, unless the soil be very rich in potassium and calcium, the application of some special manure will greatly enhance the value of the outturn. Wood-ashes are a valuable supplement to stable dung. Gypsum is an excellent dressing for soils in a good manurial condition: it supplies the lime needed by the tobacco, and acts as a solvent on the inert potash salts. Gypsum applied on poor land, however, hastens the exhaustion of the soil. It is said that crops manured with gypsum suffer less from the effects of drought, and require less irrigation, than when manured otherwise: the leaves of plants that had been manured with gypsum exhaling less water than when manured with other substances. If this assertion be correct, gypsum would be invaluable to the Indian cultivator.

With regard to the amount of manure to be employed, it may be observed that, with farmyard manure properly rotted, there is no theoretical limit, especially when the tobacco is intended for snuff, and is grown in a hot climate, where the physical properties of the soil are of the utmost importance. It is said that some Rhenish-Bavarian soils contain as much as 15 per cent. of organic matter, yet the cultivator considers it necessary to heavily manure each tobacco crop. Dutch growers apply to the rich alluvial soil as much as 25 tons an acre of well-rotted cattle-manure. In America, it is reported that the heaviest crops are obtained on soil newly taken up, and very rich in vegetable mould. It is considered nearly everywhere that tobacco will pay best when heavily manured. The first care of even the poorest peasant in the tobacco districts of Germany, Holland, &c., as soon as he sells his tobacco, is to purchase the manure which he considers essential to his success.

The amount of any special manure which can be applied without injury to the plants depends very much on the solubility of the stuff, and the manner of applying it. Highly soluble salts, such as nitrate of soda or potash, should be applied in smaller quantities than salts which dissolve slowly. With regard to the manner of applying concentrated manures, it is evident that, when a salt is applied in close proximity to the plant, less will be required than when strewn over the whole field. When applied in solution, not more than 300 lb. of nitrate per acre should be used at one time. The amount to be applied varies also with the soil; a sandy soil, which has little absorptive power, should receive less than a clay. Salts easily disintegrating should not be applied before tobacco has been planted, especially not before heavy rains which would carry off the salt. To supply the potash required by the tobacco plant, 200 lb. of good saltpetre per acre would be sufficient in most cases. Lime, although removed from the soil in large quantities, is rarely applied to tobacco as a special manure. Where wood-ashes can be had at a moderate price, lime may be applied in this form. Some ashes are very rich in lime. It has been found that ashes obtained from beechwood contain 52 per cent. of lime, and those from oak-wood, as much as 75.

Rotation.—A proper rotation of crops is particularly advantageous for the cultivation of tobacco, since it requires a great amount of readily accessible inorganic matter in the soil, especially potash and lime. Although the importance of cultivating tobacco in rotation is admitted, there may be circumstances that justify the growth of this crop consecutively for several years in the same field. In America, tobacco is grown successively for several years on new land, where the elements of plant food exist in such abundance that the crop may be thus cultivated without for a time showing any notable decrease in yield; it is even said that the outturn of the second year is heavier than that of the first. In Hungary and Holland, the best tobacco is grown for many years in succession on the same land. There the plan is adopted partly out of necessity and partly for convenience. The small landholder is often obliged to grow tobacco on the same field, because he has only one properly fitted for it; for convenience, he grows it every year on the same place near his homestead, to allow of the closest attention to the crop, but he manures heavily. Nessler, in Carlsruhe, cultivated tobacco during six consecutive years in the same field, without noticing any perceptible decrease in yield or quality. To admit of such a system, the soil must either be very rich in the essential elements, or be heavily manured, as is the practice in Holland. It is generally assumed that, when tobacco is grown on the same field in succession, the leaves do not become so large after the first year, but grow thicker and more gummy, and contain less water.

From the foregoing, it would appear that, although tobacco may be grown successfully on the same land uninterruptedly under special circumstances, the cultivator will find it advantageous to adopt some plan of rotation. Cereals and pulses are very well adapted for this purpose, the reason being that tobacco removes but little phosphoric acid from the soil, and thus leaves it rich in the element most necessary for the growth of cereals. It has also been found that hemp thrives particularly well after tobacco.

Selection of Sort.—The cultivator must carefully compare the requirements of the different sorts, and the means at his disposal to satisfy them, before making his selection. Though tobacco is a hardy plant, and grows under varied conditions, yet to become a remunerative crop, the plant should not be placed under circumstances very dissimilar from those to which it has been accustomed. By importing seed of a fine sort directly from its native land, the plants will not retain in the new habitat all their special qualities, unless climate, soil and treatment are nearly the same. Climate must first be considered. Fine and valuable tobacco is a product of tropical countries: in a warm and humid climate, by employing common means, tobacco may be made to yield a profit not attainable in less favoured regions. A warm, moist climate permits the selection of those sorts that command the highest prices; if to this be added a suitable soil, and proper treatment, the cultivation of tobacco yields a profit not easily obtainable from any other crop.

As the Havanna tobaccos command the highest prices, the cultivator nearly everywhere attempts to introduce and cultivate them. There is no great difficulty in raising plants of these varieties, but they speedily degenerate and form new varieties, if the climatic conditions, &c., are not favourable. Virginian tobacco was previously extensively cultivated, but has of late been frequently replaced by the Maryland kind. It is still much favoured by cultivators in temperate climates, as it does not require a high temperature. On account of its botanical characteristics, it is usually not much liked by manufacturers of cigars; some varieties, however, that have less of the marked specific characters, yield tolerably fine leaves for cigars. As the price of this tobacco is rather low, it is not so well suited for export. Hungarian tobacco is considered to be very hardy, but is less valuable than the foregoing. The leaves are generally small, and possess a peculiar aroma.

A high price is generally commanded, irrespective of the species, by those tobaccos that possess a large, smooth, thin, elastic leaf, possessing a fine golden colour and a good aroma; the ribs and veins should be thin, and the former should branch off from the mid-rib at nearly right angles, and should be far apart from each other. The lower the percentage of the weight in ribs, the thinner and broader the leaf, and the fewer the leaves torn, the more wrappers can be cut out of 1 lb. of tobacco, other conditions being equal, and consequently the higher is the price of the article. The cigar-manufacturer often does not appreciate the aroma so much as the other qualities. He can do nothing to improve the botanical characters: the finest aromatic leaf would be of little value to him if it were torn; but he is to a certain extent able artificially to improve defects in flavour. Of all kinds, Maryland is considered to possess the qualities that distinguish a good tobacco in the highest degree. Some of the Havanna tobaccos belong to this sort, as also the Ohio, Amersfort, Turkish, and Dutten tobaccos. Its cultivation assumes larger proportions every year, and the number of varieties and sub-varieties increases accordingly. Perhaps the finest wrappers for cigars are grown in Manilla.

Seed.—The best and strongest plants are selected for affording seed. These are not "topped" like the remainder of the crop, and are left standing when the crop is gathered. All suckers are carefully removed from the stems, and sometimes from the leaves also. When the crop is cut, the seed-stalks should be staked, to prevent their destruction by the wind. As soon as the seed-pods blacken, the seed is ripe; the heads are then cut off below the forks of the plant, and are hung in a dry and safe place to cure. Care must be taken to gather them before frost has impaired their vitality. During leisure time, the pods are stripped from the stalks, and the seed is rubbed out by hand, and winnowed. Its vitality is proved by its crackling when thrown upon a hot stove.

Seed-beds.—A very light friable soil is necessary for the seed-beds; to obtain this, it should be broken up to a depth of 1½ ft. some months before the sowing-season. A drain is dug around the beds, and the soil is utilized in raising the surface. In America, a very warm and sheltered situation, such as the south end of a barn, is selected for the seed-beds. It is a common plan there to burn a brush-heap over the ground, thus supplying potash and killing weeds. The time for sowing in America is usually from the middle of March to the 10th of April, or as soon as the ground admits of working in the spring; in India, it depends upon the locality: when the monsoon rains are very heavy, it should follow them; in other cases, it may precede them.

Unless the soil be very rich in humus, it should be heavily manured with well preserved farmyard manure soon after breaking up. The soil of a tobacco nursery cannot contain too much organic matter; the presence of much humus will prevent, to a great extent, the formation of a surface crust, which is so detrimental to the development of the plants during their early growth, and will also facilitate the extraction of the plants when transplanting takes place. After a few weeks have elapsed, the soil should be dug over a second time, and the whole be reduced to a fine tilth. The land may now remain untouched until the sowing time, unless weeds should spring up: these must be eradicated.

The area required for a nursery depends on the area of ground to be planted, and on the distance separating the plants in the field. About 1 sq. in. space should be allotted to each of the young plants in the nursery. Taking the number to be 7260 plants required for an acre (at 3 ft. × 2 ft.), and giving each plant 1 sq. in. of room, an area of 7000 sq. in. or 50 sq. ft. would raise plants sufficient for an acre. But as some are injured during growth, many rendered useless in lifting them for transplanting, and more needed to replace those that die after transplanting, double the number should be raised, or 100 sq. ft. of nursery bed for an acre.

The amount of seed required for an acre depends chiefly on its vitality. An ounce contains about 100,000 seeds, or sufficient for nearly 7 acres if all grew; but as even the best has not a very high percentage of vitality, ½–1 oz. is generally sown to produce the plants required for one acre.

Sowing-time having arrived, the nursery is divided into beds, most conveniently, 10 ft. long and 5 ft. wide, making 50 sq. ft. each, on which plants for ½ acre can easily be raised. As, even with a small tobacco plantation, several days are required for transplanting, all the beds should not be sown at one time, but at intervals of a few days. This will also lessen the risk of the young plants being all destroyed by a storm, insects, &c. Before sowing the seed, the soil is dug over to the depth of 6 in., and levelled with a rake. The seed must then be sown evenly on the surface, and beaten down slightly with the hand or otherwise. The seed being very small, many cultivators mix it with ashes, or pulverized gypsum, in order to distribute it regularly over the bed. The seed must be covered only slightly, best done by strewing a little fine compost manure over it. Ants, which often destroy the seeds, may be kept off by sprinkling some ashes over the bed. Finally cut straw may be scattered over the surface. In India, to protect the nursery from the sun and rain, the whole is covered with a roof made of straw, leaves, or cloth, supported by poles, at only a few feet above the ground. The soil must be kept constantly moist, but not wet; weak liquid-manure may be used for watering. Much time is saved by starting the seed in a warm room before sowing.

The plants, which will appear about a week after sowing, are very tender during the first stage of their growth, and require frequent watering through a fine rose. The straw will now prevent the water falling with any force immediately on the plants, and its tendency to wash the soil from the fine rootlets. If the plants spring up thickly, they are thinned out, when about a week or two old, leaving about 1 sq. in. for each. Those taken out may be used to fill blanks in the nursery bed, or, if more plants are taken out than are required for this purpose, they should be planted in a separate bed. It is universally acknowledged that plants transplanted when very young develop more roots, grow more vigorously, and become more hardy afterwards, than when not transplanted at this stage. When the plants are about two weeks old, they require less attention, and should be watered less frequently, to harden them before transplanting. Any weeds appearing must be removed, and injurious insects must be killed. In about 7–8 weeks after sowing, the plants will be fit for transplanting.

Preparation of the Field.—Land intended to be planted with tobacco should receive several ploughings not less than 9 in. deep. As a rule, clay requires to be more deeply ploughed than sandy or loamy soil. It greatly conduces to success, if the land is allowed to lie fallow for several months before planting the crop, to admit of the proper preparation of the soil, by ploughing, rolling, harrowing, &c., and to allow the attainment of as fine a tilth as is usual in gardens. No crop will better repay the expense of proper preparation of the soil than tobacco; the fineness of the leaf, and the aroma of the tobacco depend to a great degree upon this. The land should be ridged immediately before planting. The distance apart at which to make the ridges is governed by the quality of the soil and the sort of plant to be raised. With good soil, the ridges must be further apart than in a poor one, because of producing larger leaves. The ridges should allow a passage between the rows, for the purpose of weeding, hoeing, suckering, &c., without breaking the leaves. In the lines, the plants may be 6 in.–1 ft. closer than the ridges. In some places, a plough is run at right angles across the ridges before planting, at the distance at which the plants have to stand in the lines, thus forming small hills on which the seedlings are planted.

Planting.—Planting should take place only in the evening (or even at night in India), unless the weather be cloudy, when it may be performed during the whole day. Some hours before commencing to transplant, the nursery should be thoroughly watered, to facilitate the removal of the plants, without tearing their roots. If the plants are of even size, so that all can be removed, the best plan is to take them out with a spade, or trowel, leaving a lump of soil on each. But in most cases, it will be necessary to take up each plant separately; this should be done very carefully, holding with the thumb and forefinger as near as possible to the roots, and drawing out the plants, if possible, with a little soil adhering to their roots. The plants are taken at once in a basket to the field for planting. An attendant going between two ridges places a plant on each hill, right and left. One attendant is sufficient for two planters, who follow immediately. The planting is nearly the same as with cabbages, but requires more care, the plants being more tender, and their roots and leaves springing nearly from the same point, they are more difficult to handle. The plants should be placed in a hollow made on each hill, which will serve as a reservoir for the water to be applied, and also afford some shade.

In India, the plants are watered immediately after planting; they should also by some means be shaded during the first few days, which can easily be done when only a small area is planted, but is rather difficult to manage on a large scale. In the latter case, the shade afforded by planting in a slight cavity must suffice. If the plants have been taken from the nursery with some soil adhering to their roots, and are kept sufficiently moist during the first few days, few of them will die. When the weather is dry, water should be applied at morning and evening, and after that time, once daily until the plants have taken root, after which, occasional waterings, varying with soil, weather, and kind of plant, must be given. In dry weather, and with a soil poor in humus, one watering every second or third day may be necessary, whereas with a soil rich in organic matter, and in a moist atmosphere, watering may be entirely dispensed with. During the first few days, the water is applied with a watering-pot, held very low, otherwise the soil would be washed from the plant-roots, and expose them to the direct rays of the sun, causing death.

After-cultivation.—After the plants have once taken root, they grow rapidly. They are hoed when about 6–9 in. high, and the soil is drawn from the furrows to raise the hills, maintaining a depression round the stems. If the soil is not very rich, a special manure should be applied at this stage of growth. The best manure generally will be nitre in a liquid state, which can be applied in the depression around the plants with a watering-pot. By applying it in solution and close to the plant, less is required than when spread over the whole field. Some weeks afterwards, another hoeing and heaping of earth round the plants will be necessary. It is most difficult to say the number of hoeings which may be required by a tobacco crop. The general rule to be followed is to keep the soil loose, friable, and free from weeds. The more organic matter the soil contains, the more will it remain loose and friable; the less organic matter, the more waterings will be required, which causes the soil to crust over, and to assume a close texture, and necessitates frequent hoeings. As long as the plants have not spread much, the hoeing may be done by a cultivator, followed by some men to perform the heaping. Insects which attack the tobacco must be carefully sought for and killed at once. They can easily be discovered in the mornings; if not killed, they may destroy the whole crop in a few days. Turkeys are invaluable for their grub-eating propensities.

Topping and Suckering.—The plants will commence to flower about two months after planting, when 2–7 ft. high. When the flower-buds appear, they must be broken off, and with them the top and bottom leaves. By breaking off the flower-buds at an early date, the sap that would be used in the formation of these organs flows to the leaves, which thereby increase in size, and the outturn becomes much heavier than when the plant is allowed to flower. But it is generally admitted that the leaves lose much in aroma. To what extent the early removal of the flower-buds impairs the quality has not been properly investigated. It is very probable that the greater yield does not always compensate for the loss in quality. The bottom leaves are generally of inferior quality, small, torn, and dirty. The number of leaves to be left on the plant varies greatly, according to species, quality of soil, and method of cultivation. The minimum may be placed at 6, the maximum at 22. The only rule to be observed is to retain as many leaves as the plants are able to mature. Soon after the plants have been topped, suckers appear in the axils of the leaves; these should be broken off as soon as they come, at least they should not be allowed to grow longer than 4 in. If the suckers are not removed soon after their appearance, the size of the leaves will be seriously impaired. After the plants are half-grown, great care must be taken when going through the lines, whether for the purposes of hoeing, watering, or suckering, &c., not to tear the leaves. In India, hoeing and suckering should be performed only when the leaves have lost part of their turgescence, attained at night. Insects, however, must be killed during the morning and evening; at other times, they are not easily found. Leaves which are torn are not fit for cigar-wrappers, and must often be thrown on the refuse heap as valueless, even if well developed and of good colour.

The plants commence to ripen about three months after being planted; this is indicated by the leaves assuming a marbled appearance, and a yellowish-green colour. The leaves also generally become gummy, and the tips bend downwards. It is considered that tobacco intended for snuff should have attained more maturity than tobacco for smoking. Nessler found that the less ripe leaves contained more carbonate of potash, and burnt consequently better, than the more ripe ones, but the total amount of potash was larger in the latter than in the former; cigars made from less ripe leaves kept the fire when lighted for a shorter time than those made from more ripe leaves.

Harvesting.—The leaf being matured, it should be harvested only after the dew is off the plants, and not on a rainy day. There are two modes of harvesting—gathering the leaves singly, and cutting down the whole plant. Gathering single leaves admits of removing them from the plant as they ripen; the bottom leaves are removed first, and the top ones are left some time longer, until they have attained full maturity. The cultivator is thereby enabled to gather his crop when it possesses the greatest value. This plan necessitates, however, a great amount of labour, and, in a hot climate, the single leaves are apt to dry so rapidly as not to attain a proper colour, unless stacked early in heaps. But stacking in heaps involves great risk of the leaves heating too much, and developing a bad flavour, whereby the tobacco loses more or less in value. For Indian circumstances generally, cutting the whole plants is better than gathering the leaves singly.

For cutting down the plants, a long knife or chopper is used. A man takes the plant with his left hand about 9 in. from the ground, and with the knife in his right hand, cuts through the stem of the plant just above the ground. If the plants are sufficiently "wilted," he may lay them on the ground and proceed to cut down others; if, however, they are so brittle as to cause the leaves to be injured by laying them down, he should give them to another person, to carry them at once under shade. During bright weather, the plants should not be allowed to lie exposed to the sun on the ground, or they will become sun-burnt, and lose in value. A temporary shed should be erected; it might be simply a light roof of palm-leaves or thatched straw, supported by poles; a large tree standing near will also serve the purpose. Under this shade, parallel rows of posts are put up, and on the posts, light poles or strong bamboos are fixed horizontally. The parallel lines should be about 4½ ft. apart and the horizontal poles about 4–5 ft. from the ground, according to the height of the tobacco plants. Rods are cut in lengths of 5 ft., and laid over the parallel bars, so that they will project about 3 in. at each end. A very light and convenient shelter sometimes used for sun-drying in America, consists of rods laid crosswise, supported on four upright poles, and covered with a sloping roof of boards. The plants that have been cut are immediately brought into the shade, tied in pairs, and hung across the rods. They must not be hung so close as to press each other, and the rods should therefore be 6–12 in. apart. The framework should be so large as to allow of one day's cutting being hung. The plants are left thus for one day, during which time they will be wilted sufficiently to allow handling without tearing the leaves. In a very dry wind, mats or other cover should be laid against the plants most exposed to it, or their leaves will dry rapidly, shrivel up, and remain green. Next day the leaves are carted to the drying-shed. A cart supplied with a framework, in order that the plants may be hung as they were hung under the shade, is the best means. Perpendicular uprights at each corner of a cart or waggon are fixed together by horizontal poles. The plants may be hung so close as not to press heavily on each other, 200–400 being brought to the shed at one time.

Drying.—The drying-shed is prepared beforehand to receive the tobacco. When cultivating tobacco on a small scale, any shed will do, provided that it contains a sufficient number of doors and windows to admit of regulating the circulation of air. A roof made of straw seems to answer very well. The shed should be high enough to admit of hanging three rows of tobacco in it, one above the other. The bottom tier for the first row should be about 3–5 ft. from the ground, according to the size of the plants, which should not touch the ground; the second tier should be 3–5 ft. higher than the first; the third, 3–5 ft. higher than the second; the whole being 10–17 ft. high from the bottom of the shed to the highest tier. The tiers must be so arranged that the tobacco when hung on the upper tier should not touch that of the lower one, and that the rods on which the tobacco has been hung in the field fit exactly. The windows must face each other, and be placed between the tiers, so that the bottom part of the window is on the same level as the tier. When cultivating on a large scale, the same arrangements are made, but the building is higher, and is provided with a cellar, in which to place the tobacco for the purpose of stripping, &c.

The drying-shed being ready, the plants immediately on arrival at the shed are transferred from the conveyance, on the rods, to the lowest tier. No rule can be given as to the distance the rods should be placed from each other, as it varies according to the species of the plant, the degree of ripeness, and especially the state of the weather. The purpose of hanging the plant here on the lower tier is to cause the leaves to dry gradually, and assume a good yellow colour, and to create a slight fermentation in them, while allowing such a circulation of air between the plants as will facilitate the gradual escape of the moisture from them, and prevent the injurious development of ammonia and other combinations that give rise to bad flavour in the tobacco. How to attain this, exercises the judgment of the cultivator, who, by frequent examination of the plants, and by careful observation of the changes going on in the leaves, will soon find out the right way.

The rods should be placed closer together—(*a*) when the plants are much wilted on reaching the shed; (*b*) when the air is very dry, and the temperature is high; (*c*) when the leaves of the plant are very thin and contain little water. Plants which have the leaves closely arranged on the stems must be hung further apart. When the air is very dry, and there is a strong breeze, the windows must be closed. If this is not sufficient, water may be poured on some heaps of sand, to create a moist atmosphere in the shed. When the stems of the plant are very thick, and consequently contain much sap, it is beneficial to open the windows, especially at morning and evening, for some hours, that the wind may pass over the butt-ends. As the windows are situated above the lowest tier, the leaves will not be much affected by it.

The leaves must be examined carefully every day; one plant may progress very well, whereas another close by may decompose too rapidly, and another too slowly. Although no change of weather occur, it may yet be necessary to alter the position of the rods, in order that each plant and leaf may receive air in such a degree as is most conducive to its proper decomposition. Any change in the weather necessitates different arrangements. The plant should remain on the lower tier until the leaves have turned yellow, which will take place within 6–10 days, according to circumstances; after this, they are hung on the upper tiers. There they should be more apart, each plant hanging free. When on the upper tiers, the tobacco may be said to be in the free-hang; and when on the lowest tier, in the close-hang. The object in hanging the plants more apart on the upper tier is to dry them more rapidly there, and for this purpose, the shutters may be opened, unless there be a strong dry wind. The light-yellow colour of the leaves should change into a dark yellow-golden or light-brown colour. After hanging on the upper tier for about a week, the veins of the leaves will be nearly dry, leaving only the midribs pliant. The drying of the leaf and the changing of its colour proceed gradually, commencing from the margin and proceeding to the midrib. At this time, the plants are hung closer together, the evaporation from the leaves being little, and the space and sticks being required. The plants hanging on two or three sticks may be hung on one stick. All the windows may be kept open from this time; the tobacco may also be brought into an open shed, or even hung outside exposed to the sun. In about a week more, the midribs will be entirely dried up, and the tobacco will be fit for stripping. In some climates, it may be necessary to facilitate the drying by the aid of artificial heat. For this purpose, heated air should be conducted into the drying-shed, without the fire, or the products of combustion, being admitted.

Stripping.—Stripping may be performed at any time, provided the leaves, after being once properly dried, have again become pliable. For stripping, such a number of plants as will furnish work for several days are taken down on a morning, when the plants have absorbed some moisture, and have become elastic; they are put in a heap, and properly covered, to check evaporation. If, however, the night air should be so very dry that the leaves cannot absorb sufficient moisture to become pliable, a moist atmosphere can be created either by steam, or by pouring water on the floor, or by keeping vessels with water in the shed. If this cannot be done, the tobacco must remain hanging until there is damp weather. Under no condition should the tobacco be stripped when not pliant, that is if the leaves are so brittle that they would break when bent or rolled. The best arrangement is to keep the drying-shed and stripping-room separate, since the latter requires to be more moist than the former. A cellar under the drying-shed is best suited for stripping. It should be large enough to admit of the erection of a scaffold to receive the tobacco.

Sorting.—Tobacco intended for smoking should be carefully sorted when stripped. There should be four sorts: 1st, large, equally good coloured, untorn leaves; 2nd, leaves of good size and colour, but torn; 3rd, leaves of inferior colour, and bottom leaves; 4th, refuse, shrivelled up leaves, &c., to which may be added the suckers. No. 1 leaves, when thin, elastic, and of good sorts, are mostly valued as wrappers (outside covers) for cigars. No. 2 may also be used as wrappers, but are less valued than No. 1.; they are adapted for fillers and cut tobacco. The different sorts are kept separate. The best plan is to let the most intelligent man strip the leaves from the stem, and at once separate them according to quality. The leaves should then be made into hands, i. e. 10–20 leaves should be tied together by twisting a leaf round the end of the stalks, each sort being attended by a special man, to avoid mixing. The leaves of the first sort being large, 10–15 will be sufficient for a hand; more are required of the other sorts. When making the hands of the two first sorts, each leaf is taken separately, smoothened on a flat board, and left there while another is treated in the same way, continuing thus until a sufficient number is ready to make a hand. When the hand is ready, it is laid aside, and a weight is placed upon it to keep the leaves smooth.

Bulking.—Bulking means placing the tobacco-leaves in heaps for the purpose of heating, in order to develop colour and flavour; this is carried out in various ways, nearly all involving great labour and risk, as in most instances tobacco loses more or less in value during the process called "curing." The more care is taken in raising the crop, the less attention the tobacco requires in the shed. With a good kind of tobacco, grown on light, friable soil, treated as described, little care will be needed, after the leaves are dried and stripped. By the drying process, the leaves will have undergone a slow fermentation, which makes it unnecessary to watch or guide a regular fermentation afterwards, hence bulking and fermenting, as generally understood, are not required.

After being made into hands, the tobacco is put into heaps (bulked) before it again dries. Every evening, the tobacco that has been stripped during the day is bulked; but if the weather be very dry, it must be bulked as soon as a certain number of hands is ready. The heaps should be made 4–8 ft. square and 4–8 ft. high; all the stalks are outside, and the whole is covered by mats, &c., to check evaporation. The drier the tobacco, the larger must the heaps be made, to encourage a slight fermentation. The extent of the fermentation can be easily controlled. If the colour of the leaves is not uniform, or if it is desired to give them a browner colour, the heaps must be made large, and a somewhat moist atmosphere is required in the storing-room. This will cause fermentation to set in after a short time, and the heat to rise after some days, so much so that rebulking is required, which is done by putting the top leaves of the old heap at the bottom of the new one. Under such circumstances, the heap must be frequently examined during the few first weeks, to prevent overheating. It is advisable to rebulk the tobacco also, even when not much heated, after the first fourteen days, and again a month later, to ascertain the exact state in which it is. Sometimes the tobacco becomes mouldy; this occurs especially with tobacco which has been manured with chlorides, which cause it to become more hygroscopic than when manured otherwise. If this occurs, the mould must be brushed off, and, if necessary, the tobacco be dried. The tobacco may now remain heaped in the store-room until there is a chance for sale. It must be remembered, however, that the best time for selling varies very much. Some tobacco is fit for smoking a few weeks after drying, whereas others may burn very badly at that time, yet become a good burning article after being stored for several months.

Packing.—Tobacco in America is commonly packed in barrels, the layers being at right angles to each other alternately, and the butt-ends being always towards the outside. The usual size is about 4 ft. 6 in. deep, 3 ft. 6 in. in diameter at one end, and 3 ft. 4 in. at the other, to enable the contents to be uncovered for examination without disturbing the mass. The packing is effected under considerable hydraulic pressure. Elsewhere all kinds of packages are employed, and their weights are very various.

Improving.—It is sometimes the custom to subject the tobacco-leaves to some sort of improvement. There is no doubt that, by proper application of ingredients, the value of tobacco may be much enhanced. The most costly tobacco often commands a high price, not so much on account of its inherent flavour, as from that given to it artificially. In most instances, the best course to be adopted is to leave the improvement of the leaves to the manufacturer. Many ingredients are employed to improve smoking-tobacco. They tend:—1, to make the tobacco more elastic and flexible; 2, to remove the coarse flavour; 3, to add a particular flavour; 4, to improve the burning quality; 5, to improve the colour. To make the tobacco more flexible and pliant, the leaves are macerated in, or sprinkled with, a solution of sugar. In hot countries, this process is often necessary, to give tobacco such an elasticity as to fit it for handling, especially when intended for wrappers. To remove the coarse flavour, it is often macerated in water, or in very dilute hydrochloric acid. In Holland, 4–8 oz. of hydrochloric acid, diluted with 25–30 measures of water, is applied to 100 lb. of tobacco. The coarser the flavour of the tobacco, the stronger is the solution used. The time of maceration varies between ½ and 1 hour. Sometimes tobacco is steeped in a mixture of sugar solution and diluted hydrochloric acid. To extract the fatty matter, it is macerated in alcohol or spirit of wine. To give a fine flavour, numerous substances are employed, some of which are kept secret. The following ingredients are mostly in use:—Water, cognac, vanilla, sugar, rose-wood, cassia, clove, benzoin, citron oil, rose-wood oil, amber, thyme, lavender, raisins, sassafras-wood, saltpetre, orange, and many others. The burning quality is improved by macerating in or sprinkling with solutions of carbonate of potash, acetate of potash, acetate of lime, or saltpetre, &c. Badly-burning cigars inserted for a moment in such solutions are much improved. Tobacco treated with acetate of lime yields a very white ash. The colour is sometimes improved by fumigating the leaves with sulphur, and by the application of ochre and saffron.

Although it may be said that fine tobaccos generally do not require any impregnation with foreign matter for the sake of flavour, yet the manufacturer frequently endeavours to give the leaf a particular aroma. An inferior tobacco, however, which often would not find a market, is sometimes so much improved by artificial means, as to compete successfully with the genuine fine article. It is said that in Germany indigenous tobacco is often so much "improved" that the cigars made from it, after being covered with a fine tobacco leaf, are sold as genuine Havanas. A special preparation of tobacco for snuff is seldom attempted by the cultivator. With reference to the preparation of tobacco for export, the sorting of the leaf is of the utmost importance; only first and second sorts should be exported. It would be well to remove the mid-ribs, whereby the cost of transport and customs duty would be greatly reduced.

The value of a cigar depends, not only on the intrinsic value of the leaf, but to a great extent on the mode of manufacture. Thus, the raw material may be of good quality, but if the maker does not classify the leaves properly, or if he rolls his cigars too hard, which must vary according to the qualities of the leaves, the cigar will burn badly. The best-burning leaves must always be used for wrappers. If this should be neglected, the inside of the cigar burns faster than the covering, the air has no access to the burning parts, and the empyreumatical substances are volatilized without being decomposed. Such cigars therefore make much smoke, and smell badly.

Production and Commerce.—Details concerning the different modes of cultivating and curing, and of the extent of the production and commerce in tobacco in the various countries, will best be given in the alphabetical order of the countries.

Afghanistan.—The tobacco grown at Kandahar is celebrated in all the neighbouring states for its mild and agreeable flavour, and is largely exported to Hindustan and Bokhara. Three kinds are grown, viz.;—Kandahari, Balkhi, and Mansurabadi. Of these, the last named is the most esteemed, and fetches the highest price, viz., 6 lb. for 2*s.*–4*s.* The Kandahari sells for a little less than half this price, and the Balkhi for a little more. The Mansurabadi is not much exported, being mostly consumed in the country. The cultivation is conducted with great care, and the same plants yield two crops of leaves in the year. Of these, the first, which is called *sargul*, is the best, the leaves having a mild and sweet flavour; it is mostly consumed by the wealthy classes, or exported. The second crop is called *mundhai*: the leaves have a tough and fibrous texture, and a strong acrid taste; it is usually smoked by the poor people, and is also made into snuff. The plants are raised from seed in small beds, prepared for the purpose by careful manuring with wood-ashes and stable-refuse mixed together. From these nurseries, the young plants are transplanted into the fields, previously prepared for their reception, the earth being laid out in regular ridges and furrows. The plants are fixed into the sides of these little ridges, and watered by means of the intervening furrows. Often the young plants, packed in moist clay, and bound up in straw, are conveyed to distant parts of the country; but the produce of these, it is said, does not equal that of the plants reared at Kandahar. About six weeks after transplanting, that is, about May–June, the first crop is reaped, the whole plant being cut away about 6 in. from the ground, and only some five or six of the lowest leaves being left. Each plant, as cut, is laid on the ridge, and here each side is alternately exposed for a night and a day to the effects of the dew and sun, by which their green colour becomes brown. After this, they are collected in large heaps in a corner of the field, and covered over with mats, or a layer of straw, &c., and allowed to remain so for 8–10 days, during which the stems shrivel, and give up their moisture to the leaves. At the end of this time, the heaps are conveyed away into the villages, where the stalks are separated from the leaves, the latter are then dried in the shade and tightly packed in bundles about 14 in. square, and in this shape are sold by the grower. After the first crop is gathered, the ground is turned with a spade, well manured, and freely irrigated. In due course, the old stems shoot up and produce fresh leaves, and in six weeks or two months, the second crop is cut. Sometimes, though seldom, a third crop is realized, but the quality of this tobacco is very inferior, and only fit for making snuff.

Africa.—The tobacco-plant extends throughout Central and E. Africa, wherever the equinoctial rains fall. It is cultivated to some extent in the Bondei of Usambara, but seems to be the special product of the Handei district, whence considerable quantities are sent to Pangani for export. Usambara also exports to Zanzibar stiff, thin, round cakes, which have been pounded in wooden mortars, and neatly packed in plantain-leaves. It is dark and well-flavoured. The Cape of Good Hope, in 1865, had 933 *morgen* (of 2·116 acres) under tobacco, yielding 1,632,746 lb.; in 1875, 1243 *morgen* afforded 3,060,241 lb. Tobacco is grown considerably in Oudtshorn and other districts of the Cape Colony, and on the warmer farms in the Transvaal, but to the greatest extent on the coast. The supply is already sufficient for local demands, and tobacco promises to become a staple of S. African agricultural industry.

Algeria.—Tobacco-growing is a very important industry in Algeria. The culture and manufacture are quite free, but the French Government buys all the best produce, for manufacture and sale by the State factory in Paris. The cultivation continues to increase, and is highly remunerative where the land is capable of irrigation. In 1876–7, the 1889 Europeans engaged in it cultivated 2471 *hectares* (of 2½ acres), and produced 2,782,500 *kilo.*; the 8021 natives cultivated 4154 *hectares*, which yielded 1,889,124 *kilo.* The year 1877–8 was less favourable, and the area decreased by 425 *hectares.* Still worse results were expected in 1878–9, owing to scarcity of water. The kind most grown is called *chebli.* The produce per *hectare* of fine and *chebli* is estimated at 6–8 *quintals*; the other kinds give 10–12. The exports in 1877 and 1878 respectively were as follows:—Manufactured, 121,090 *kilo.*, and 124,117 *kilo.*; unmanufactured, 3,445,441 *kilo.* and 1,509,266 *kilo.* In 1879, 1087 Europeans planted 3180 *hectares*, and gathered 1,226,181 *kilo.*; 11,079 natives planted 6584 *hectares*, and produced 1,384,802 *kilo.*; the exports were 2,481,218 *kilo.* unmanufactured, and 146,345 *kilo.* manufactured.

Australia.—In the year ending 31st March, 1879, New South Wales had 835 acres under tobacco, and the crop amounted to 7932 cwt. In the same year, Victoria cultivated 1936 acres, which yielded 15,662 cwt., valued at 43,853*l.* Queensland grew 36 acres of tobacco in 1879.

Austro-Hungary.—The manufacture and sale of tobacco is a Government monopoly in the Austro-Hungarian Empire, and the revenue thus derived is the most lucrative item of the indirect income of the State. The only tobacco-growing provinces of Austria are Galicia and Bukowina, producing about 4 million *kilo.* from 2900 *hectares*; and S. Tyrol, where 290 *hectares* yield almost 4 million *kilo.* of green tobacco. The respective approximate values of the two products are 18⅓ *florin* (of 1*s.* 11½*d.*) and 4⅔ *florin* per 100 *kilo.* The chief supplies are furnished by Hungary, which was once so noted for its tobacco, but the industry is now completely crippled by the fiscal regulations. The area (in acres) under cultivation fluctuates remarkably; in 1860, it was 679¼; in 1865, 68,141; in 1869, 843¾; in 1875, 26,817; in 1879, 7316. The total areas (in acres) under cultivation in the whole empire in 1876, 1877, and 1878 respectively were: 144,493, 148,126, 143,447; the yields in *kilos.*; 46,033,163, 44,164,038, 40,978,540; and the yield (in *kilos.*) per *joch* (of 1·43 acre): 445, 426, 408. Fiume, in 1877, exported by sea 2862 cwt. of manufactured tobacco; and by land, 31,200 cwt. of leaf, and 53,712 cwt. of manufactured. In 1879, it shipped 9900 *kilo.* of leaf tobacco direct to England.

Borneo.—Tobacco is grown in small quantities by the Dyaks and people of Bruni; but they are unskilful in its manufacture, though the flavour of the product of Bruni is much esteemed by Europeans. Under skilful management, and by introducing a better kind if necessary, it might become as profitable to this island as it now is to the neighbouring ones of the Philippines, Java, &c. The Dyaks might be more readily induced to cultivate this plant, the nature of which they know, than plants which are strange to them.

Brazil.—In Brazil, tobacco is chiefly cultivated in the provinces of Bahia, Minas, Sao Paulo, and Para. The town of Purificaçao, in Bahia, is the centre of an important district. The cultivation is increasing, and greater care is being taken in the preparation. The common up-country method is to pick the leaves from the stalks, dry them under the hut-roofs, remove the midribs, and spread them in superposed layers, amounting to 2–8 lb., for rolling together and binding with bark strips. These rolls are bound very tightly with cord, and left for several days, when the cord is replaced by strips of *jacitára*, the split stem of a climbing palm (*Desmoncus sp. div.*), and have a stick-like form 1½ in. in diameter. They are sold in *masas* of 4–6 ft. in length, but the tobacco is not considered good till it has fermented for 5–6 months, when it is hard and black, and shaved off as required for pipes, cigarettes, and cigars, the last made with wrappers of *tauari* bark (*Couratari guianensis*). The Tapajos tobacco is considered the finest in the Amazon valley. The export of tobacco from Bahia in 1877–8 was 17,272,678 *kilo.*, and in 1878–9, 18,149,201 *kilo.*, almost the whole being to Germany. Santos, in 1878–9, shipped 381,310 *kilo.* Bahia sends away immense numbers of cigars coastwise. Maceio exported 4336*l.* worth in 1876, but none in 1879.

China.—The chief tobacco-growing provinces of China are Chihli, Hopih, Hoonan, Szechuen, and Shingking. The use of tobacco is wide-spread and common, and considerable local trade is carried on in it. The exports from Amoy were 2573 *piculs* (of 133⅓ lb.), value 13,561*l.*, in 1877; and 3994½ *piculs*, value 17,936*l.* in 1878. Wenchow exported 27¾ *piculs* of leaf in 1878, and 321⅓ in 1879. The exports and re-exports from Hankow in 1878 were 65,070¾ *piculs* of leaf, and 46,241¾ of prepared. In 1879, Hankow exported and re-exported 63,180 *piculs* prepared, value 311,754*l.*, and 58,094 of leaf, value 118,534*l.* There is an immense supply from the provinces, and the leaf is fine in colour, texture, and fragrance, but though sent to America and England for cigar-making, the trade has not been remunerative. It is now used in cigarettes and various cut mixtures as "Turkish," but when better known, will be smoked on its own merits. Canton exported 1730¾ *piculs* in 1877, 1742¾ in 1878, and 2397 in 1879. The exports of leaf from Ningpo were 407 *piculs* in 1874, 571 in 1875, 211 in 1876, 530 in 1877, 378 in 1878, and 165 in 1879. Kiungchow exported 449¼ *piculs* of leaf in 1878; and 85½ *piculs*, value 136*l.* in 1879. Kiukiang exported 28,120½ *piculs* of leaf, value 35,678*l.*, in 1878; and 14,659 of leaf, and 802 of stalk, in 1879.

Chinkiang imported 13,328 *piculs* of leaf, and 1914 of prepared in 1879. Macao receives tobacco from the Hokshan district, and prepares it for exportation to Java, the Straits, and California, the annual export being about 10,000 *piculs.* The Newchwang imports of prepared native tobacco were 8052 *piculs* in 1877, 8354 in 1878, and 6630 in 1879. Shanghai, in 1879, imported 58,460 *piculs* of native leaf, 79,081½ of prepared, and 1187½ of stalk; and exported and re-exported 31,541 of leaf, and 29,672¼ of prepared. Taiwan imported 3017¼ *piculs* of prepared native in 1879. Tientsin exported 1047⅓ *piculs* native tobacco in 1878, and 693½ in 1879. Tobacco is grown in the hilly districts near Wuhu; the leaves are gathered in October, and sun-dried on wicker-work frames. The exports in 1879 were 597½ *piculs* of leaf, and 742 of prepared.

Cochin-China.—The culture of tobacco is extending in Cochin-China, and it is even said that a considerable quantity is exported to China, but it improves little in quality. The area reported to be under tobacco-cultivation in 1878 (including coffee) was 2361 acres.

Ecuador.—The tobacco-crop of Ecuador for 1879 was not so large as usual, owing to an unfavourable season. Esmeraldas, the most northerly port, and whence nearly all the tobacco shipments are made, despatched about 3000 *quintals* in 1879. Guayaquil exported 150 *quintals* in 1877, none in 1878, and 10 in 1879.

Fiji.—The Fiji Islands are well adapted to tobacco-culture. The natives produce a good deal, which nearly approaches the American leaf. With careful curing, it would find a market in England. The native product is rolled, which prevents its being made into cigars. Samples of leaf-tobacco in hands, raised from foreign seeds, exhibited very unequal qualities, and a tendency to revert to American forms, the Havana returning to the Virginian type. Cut up for smoking, they were deficient in flavour, but were considered satisfactory as a first experiment.

France.—The area occupied by tobacco in France in 1873 was 14,858 *hectares* (of 2½ acres), yielding at the rate of 12 *quintals* (of 220½ lb.). The amount of land authorized to grow tobacco in Pas de Calais in 1879 was 2100 acres, and the quantity furnished to the Government was 3,659,636 lb., the prices (per *kilo.*) paid by the Government being 1 *fr.* 45*c.* for 1sts, 1 *fr.* 12*c.* for 2nds, 88*c.* for 3rds, and 10–66*c.* for other inferior qualities. The number of plants grown per acre is about 17,000. The department Nord affords rather more than Pas de Calais.

Germany.—The total area of land engaged in growing tobacco in Germany in 1878 was about 44,520 acres; nearly two-thirds of this total was distributed among Rhenish Bavaria, Baden, S. Hesse, and Alsace-Lorraine. The total consumption of tobacco in the German empire in that year was 2,196,000 cwt. The home production was 596,776 cwt., the remainder being imported.

Greece.—The production of tobacco in Greece is about 4 million *okes* (of 2¾ lb.) annually. Patras, in 1878, exported 300 tons to Holland, Austria, and Turkey, at a value of 25–30*l.* a ton. The values of the exports from Syra, in 1879, were 3503*l.* to Great Britain, 2325*l.* to Turkey, 88*l.* to the Danubian Principalities, 236*l.* to France, 554*l.* to Austria, 436*l.* to Egypt, 1605*l.* to Russia; and in 1878, 1528*l.* to Turkey, 1875*l.* to Great Britain, 93*l.* to the Danubian Principalities, 441*l.* to Austria, 334*l.* to France, 266*l.* to Russia, 39*l.* to Egypt.

Holland.—There were 4117 acres under tobacco in Holland in 1878, which produced 3,132,875 *kilo.*

The imports of tobacco into Holland in 1878 were as follows:—Maryland, 5249, Kentucky, 500, and Virginian, 107 hogsheads; Java, 87,998, seed leaf, 100, Sumatra, 33,671 packages. In 1876 and 1877, there were 5900 and 3993 packages respectively from Rio Grande. The exports of leaf from Holland in 1879 were 3,900,000 *kilo.*

India.—An immense area is occupied in producing tobacco in India. In Madras, Dindigul is the great tobacco district, and cheroots are manufactured at Trichinopoli. The islands in the delta of the Godavari also yield *lunka* tobacco, the climate being suitable, and the plants being raised on rather poor, light soil, highly manured and well watered. Manilla seeds have been tried on the lower Palnai Hills, but the Wynaad has proved to be the best locality. In Bombay, the Kaira and Khandesh tobaccos are superior; altogether over 40,000 acres were under the crop in this presidency in 1871–2, and the exports were 3 million lb. Shiraz and Manilla seeds yield good plants in Gujrat, and Khandesh. The total areas under tobacco in 1871–2 were thus returned:—Bengal, about 300,000 acres; Punjab, over 90,000; Oudh, 69,500; Rungpore, 60,000 (affording the so-called "Burma cheroots"); Central Provinces, 55,000; Tirhoot, 40,000; Cooch Behar, 24,000; Mysore, 20,000; Dinagepore, 20,000; Purneah, 20,000; Behar, 18,500; Burma, 13,000; Monghyr, 9–10,000; Nuddea, 9–10,000. The best tobacco districts are said to be Sandoway and the island of Cheduba, in Arracan; Rungpore, in Bengal; and Bhilsa, in the Central Provinces. The results of many analyses of S. Indian tobaccos show that their ash seldom contains more than 5–6 per cent. of carbonate of potash, while American range from 20 to 40 per cent., indicating the poverty of the Indian soils in this important ingredient. It might, however, be supplied at moderate cost in the shape of saltpetre, which is actually exported largely from the tobacco-growing districts.

The bulk of the Indian tobacco exported consists of leaf, the kinds chiefly shipped being the "Bispah" and "Poolah" varieties of the Rungpore kind; the quantities of cigars and other manufactured tobacco exported are very small. The exports in lbs. for the last four years were:—

	1875–76.	1876–77.	1877–78.	1878–79.
Unmanufactured	22,861,711	10,508,720	10,594,604	13,279,158
Manufactured:				
Cigars	152,189	190,136	189,742	196,759
Other sorts	232,720	205,033	317,887	247,743
Total	23,246,620	10,903,889	11,102,233	13,723,660

On the other hand, a considerable quantity of manufactured tobacco, averaging over 1½ million lb. yearly, is imported, showing that India is still merely a producer of raw material, and is dependent upon other countries for the manufactured article in a condition fit for consumption. Even as regards the raw material, India might do a great deal more than at present, for there would be a large and constant demand on the continent of Europe for Indian leaf, if it could be obtained of somewhat better quality. The French and Italian tobacco departments are prepared to take Indian tobacco in large quantities, if it can be supplied of a quality suited to their purposes; and there would also be an extensive demand from Austria and Germany. Although the shipments consist mainly of leaf tobacco, and that not of good quality, tobacco-manufacture is now making a promising beginning. In the enterprise being carried on at Ghazipore, in the N.-W. Provinces, and at Poosah, in Bengal, both the cultivation and manufacture are under the supervision of skilled American growers and curers. Some of this tobacco sent to the *Administration des Tabacs* in Paris has been very favourably reported on. The factory at Ghazipore is now turning out about 500 lb. a day of all classes, the greater part being black cavendish and honeydew, for the army. The machinery is capable of turning out 3500 lb. a day, as soon as sufficient hands have been trained.

Hitherto no Indian tobacco has realized any valuation approaching that of American. The average price of the American "shipping tobacco" is 5–6*d.* a lb., higher classes of bright leaf from Virginia realize as much as 7–13*d.* a lb., while the price of Indian tobacco has generally been 1–2*d.* a lb. But the 15,000 lb. of Poosah leaf from the 1877 crop reached England when American shipping leaf was at 4–5*d.* a lb., or 25 per cent. below the normal rate. The consignment was, moreover, packed in rather damp order, and contained a quantity of moisture which caused it to be assessed under the highest rate of the new tariff, which imposes 3*s.* 10*d.* duty when the moisture is over 10 per cent., against 3*s.* 6*d.* under 10 per cent. This made a difference in the value, estimated at 1*d.* a lb. The price obtained was 3¾*d.*, which would have been 4¾*d.* had the tobacco been drier, and the sale has been followed by orders of large shipments.

The high prices, too, realized for the best samples of the 1876 and 1877 crops, indicate that Indian leaf can be turned out equal to the best shipping tobacco from America. A tierce of strips from the 1876–77 crop from Ghazipore sold for 7*d.* a lb., and the greater part of the rest for 5*d.* or more, while a portion of the Poosah leaf of 1877–78 was valued at 5*d.* when the market was 25 per cent. below normal rates. These facts seem to guarantee future success, since the quantity of the higher classes can be largely increased, and a greater portion of the crop be brought to the same higher level. The chief point to be ascertained was whether a sufficiently high level could be attained at all. It has been attained. The cured leaf of 1878 is very much superior to any hitherto turned out, especially that from Ghazipore. A new market is not unlikely to open in France. The French Government have already asked for a consignment for trial of 1000–1500 lb.

The reason why the manufacture of smoking tobacco for Indian consumption has occupied so large a share in the operations is, that the Indian market, though small, pays far more handsome profits than the English market. The price paid for reasonably good American manufactured tobacco in India ranges from one to three *rupees* a lb. Ghazipore and Poosah tobacco is sold at half that price, at a much higher profit than can be obtained by sending cured leaf to England.

While Indian cured leaf can find a sale in the English market at prices which will enable it to compete there with American cured leaf, Indian manufactured leaf is proved to compete successfully with American manufactured leaf in India itself, with a fair prospect of success in a similar competition in the colonies. It may be stated in general terms that 4*d.* a lb. for cured leaf in England, and 6–10 *annas* for manufactured leaf in India, will secure sufficient or even handsome profits. The opening for profits will perhaps be better understood if it is explained that 1*d.* a lb. represents an asset of about 5*l.* an acre. The one great advantage which India has over America is cheap labour. It is now proved that the leaf is, for all practical purposes, as good as the American leaf, and there is hardly any doubt that America cannot afford to send home leaf at the price at which India can sell.

The exports of tobacco from British India during the years 1874–5 to 1878–9 have been as follows:—

		1875.	1876.	1877.	1878.	1879.
Unmanufactured ..	lb.	33,411,504	22,861,711	10,508,720	10,594,604	13,279,158
Manufactured	lb.	425,040	384,909	395,169	507,629	444,502
	No.	2,999,940	..	..	..	..

Italy.—Tobacco is cultivated in Italy in the provinces of Ancona, Benevento, Terra di Lavoro, Principato Citeriore, Terra d'Otranto, Umbria, Vicenza, and Sardinia. The area and produce in the following years were:—in 1870, 9544 acres, 67,192 cwt.; 1872, 12,256 acres, 82,349 cwt.; 1874, 8202 acres, 90,300 cwt. The exports from Naples in 1879 were 2006 *kilo.*, value 401*l.*

Japan.—Japanese tobacco is well-known in the London market, but it is often in a soft condition, and then scarcely saleable. More care is needed in drying it before packing.

Java.—Tobacco, termed by the natives *tombáku*, or *sáta*, is an article of very general cultivation in Java, but is only extensively raised for exportation in the central districts of Kedu and Banyumas. As it requires a soil of the richest mould, but at the same time not subject to inundations, these districts hold out peculiar advantages to the tobacco-planter, not to be found on the low lands. For internal consumption, small quantities are raised in convenient spots everywhere. In Kedu, tobacco forms, after rice, by far the most important article of cultivation, and, in consequence of the fitness of the soil, the plant grows to the height of 8–10 ft., on lands not previously dressed or manured, with a luxuriance seldom witnessed in India. Cultivated here alternately with rice, only one crop of either is obtained within the year; but after the harvest of the rice, or the gathering of the tobacco-leaves, the land is allowed to remain fallow, till the season again arrives for preparing it to receive the other. The young plant is not raised within the district, but procured from the high lands in the vicinity, principally from the district of Kalibéber, on the slope of the mountain Diéng or Práhu, where it is raised and sold by the hundred to the cultivators of the adjoining districts. The transplantation takes place in June, and the plant is at its full growth in October. The exports in the year 1877–8 were 212,500 *piculs* to Holland, and 213 to Singapore; in 1878–9, they were 248,566 *picu's* to Holland, and 872 to Singapore. The value of the export to Holland in 1879 was stated at 1,250,000*l.*

Persia.—The whole of the eastern coast of the Black Sea, i. e. Mingrelia, Lazistan, Abkhasia, and Circassia, is admirably suited for tobacco cultivation. The country between Poti and Súkhúm Kalé contains admirable sites for tobacco-plantations, labour for which can be got from Trebizond. A great demand for tobacco of good quality exists in the country, and a practical planter should do well. A quantity of coarse, badly-cured tobacco, of no commercial value, is produced in Imeritia and Georgia. Great success has attended the culture in Ghilan. The first seed introduced was from Samsoun; since then Yenija seed has been tried, and some parcels attained the standard of the best Turkish tobacco. It can be produced at about 20*s.* a *pood* (of 36 lb.), giving a profit of

22*s*. a cwt. Hitherto the cultivation has been confined to the plains, where both soil and atmosphere are damp, but it might be worth trying the hill-skirts. About 2000 cwt. were produced in 1878. The exports of tobacco, the produce of Ghilan, from Resht to Russia were valued at 4615*l.* in 1878, and 6154*l.* in 1879. The values (in rupees) of the exports in 1879 were 13,000 from Bushire, 73,500 from Lingah, and 35,000 from Bahrein.

Philippines.—The soil and climate of the Philippines are eminently suited to tobacco-culture; but the unjust Spanish monopoly cripples the industry, and it is declining. Next to the Cuban (Vuelta abajo) and a few prime Turkish sorts, Manilla tobacco is admitted to be the best. Most of the Philippines produce it. According to the quality of the produce, the provinces rank as follows:—(1) Cayagan and Ysabel, (2) Ygorrotes, (3) Island of Mindanáo, (4) Bisayas, (5) New Ecija. On the average, over 400 million cigars, and a quantity of tobacco sufficient to bring up the total weight to 56,000 cwt., are annually exported. The advantage of the plantations in Cayagan lies in the annual deposit of alluvial matters by the overflowing of the large streams. The cultivation in Bisayas promises to become extinct, whereas if the natives were free to sell in the best market, the industry would increase immensely. The yield of the Cebu district in 1878 was 8780 *quintals*, the whole of which went to the cigar factories of Cadix and Alicante. The exports from Manilla were:—in 1877, 17,526,700 lb. tobacco, value 525,801*l.*; 87,007,000 cigars, value 243,619*l.*; 1878, 15,630,400 lb. tobacco, value 468,918*l.*; 136,835,000 cigars, value 383,136*l.*; 1879, 9971 *quintals* (of 101½ lb.) tobacco leaf to Great Britain, and 74,490 *quintals* to Spain; cigars, 10,571,000 to Great Britain, 6,557,000 to Australia, 44,586,000 to the Straits Settlements and India, 25,861,000 to China and Japan, 693,000 to the United States, 100,000 to California, 1,521,000 to Spain and the Continent; the total values amounted to 480,263*l.* The exports of tobacco from Yloilo were 25,454 *piculs* (of 133⅓ lb.) in 1878, and 20,600 *quintals* (of 101½ lb.) in 1879, all to Spain.

Servia.—It is estimated that there are 4000 acres under tobacco-culture in Servia.

Spain.—The port of Cadiz is a great centre of the tobacco industry. The imports here in 1878 were:—123 *kilo.* from Germany, 304,538 *kilo.* from the United States, and 6,776,900 *kilo.* from Spanish colonies; the exports were 15,600 *kilo.* to Germany, and 213,846 *kilo.* to France.

Turkey.—The Turkish Empire has long been known as producing some of the finest tobaccos in the world. In the sanjac of Drama, which forms the vice-consular district of Cavalla, tobacco is the staple article of production and industry, and some 75,000 acres were devoted to its culture in 1873. The whole crop of 1871 was reckoned at 11,200,000 lb., the exports having been 7,600,000 lb., value 37,825*l.* The tobacco of this district, though derived entirely from one species, is divided into two classes, known as *Drama* and *Yenidji*. The former leaf is larger, stouter, and more potent, and generally of deep reddish-brown colour; the latter is smaller, slighter, less narcotic, with a peculiarly delicate aroma, and the best is of a rich yellow colour, whence its name "golden-leaf." The *Drama* kind is principally grown in the western portion of the district, and is the class supplied to European markets. The differences in the two kinds seem to be due solely to the soil.

The plantations in the Drama district proper occupy both plain and hill-side. The produce of the former is much the more considerable, and superior. The best leaves, distinguished by a stronger and more substantial texture, and a dark-red hue, go to Constantinople; the inferior and lighter-coloured find a sale in Russia. The mountain product is much inferior in quality and is sent chiefly to Europe. When the leaves are petiolate, or furnished with stems, they are made up in *manoks* ("hands") of 10–15, and termed *bashi-baghli* ("head-tied"); when the leaves are sessile, or devoid of stems, they are simply pressed together in small numbers, and called *bassma*. The whole produce of this locality varies from 2,100,000 to 2,450,000 lb. yearly. The growth obtained in the Vale of Pravista is known as *Demirli*. It is inferior, unsubstantial, and dark-coloured, and usually made up as *bashi-baghli*. The annual production is about 2 million lb.; the exports to England were 1,600,000 lb. in 1871. Cavalla affords yearly about 300,000 lb. of inferior quality, chiefly as *bashi-baghli*, and mostly consumed locally. The shipping port for all these places is Cavalla.

The district of Sarishaban produces on the average about 2,000,000 lb. annually, but the crop of 1871 reached 2,800,000 lb. About ⅞ is as *bashi-baghli*. That grown on the plain and hills is termed *ghynbek*, and forms the bulk; that from the slopes, about 500,000 lb. a year, is the best, and is known as *ghubek*. All is packed up in small *boghchas* (parcels), of 30–50 lb., which are distinguished as *béyaz*, from the white cotton wrappers used for the best sort, and *kenavir*, from the canvas coverings of the inferior kinds. The best goes to Constantinople, secondary to Smyrna and other home markets, and the worst to Europe. The district of Yenidji, near the Gulf of Lagos, affords some 3,500,000 lb. per annum, chiefly as *bassma*, and bearing a very general resemblance to the produce of Sarishaban. The best goes to Constantinople and Russia. Ghiumirgina (Ghumurdjina, or Komuldsina), grows about 300,000 lb. yearly of dark-coloured *bassma*, of the *Drama* class, which is used locally; and Sultan-Yeri gives 400,000 lb. of still darker *bashi-baghli*. The produce of these districts is shipped at Lagos (Karagatch) or Cavalla.

The most delicate and valued of all the tobaccos raised in this portion of European Turkey is the celebrated "golden leaf" from the caza of Yenidji, on the Vardar (Nestus) river. After it, in declining order, come the products of Drama, Persoccian, Sarishaban, Cavalla, and Pravista. Of the whole Drama and Yenidji produce, it is estimated that Austro-Hungary takes 40 per cent. Italy buys annually about 150,000–200,000 kilo. France, Germany, and Switzerland receive very little. Russia is a large customer. Before the war, considerable quantities were sent to the countries on the Lower Danube. England imports every year some 10,000 bales, or 400,000 *okes* (of 2·83 lb.) of Pravista tobacco. The *refusa*, or waste leaves, &c., is sent everywhere for making into cigarettes, most largely perhaps to Egypt. A kind of tobacco known as *ayiasoulouk* is grown in considerable quantities in the opium districts, almost exclusively for export to Europe, the natives having a strong prejudice against it.

The necessity for manuring is well understood by the Turks. They dress the seed-beds with goat- and sheep-dung, and manure the fields during winter with horse- and cattle-dung. In the spring, sheep and goats are folded on the land. The soil of tobacco lands will be found quite impregnated with ammonia and nitrate of potash, both absorbed by the plant; the former is thought to influence the aroma, and the latter may be seen in crystals on the surface of the dried leaf. In order to keep the leaves small and delicate, the planting is performed very close, the usual distances being 5 in. apart, and 9 in. between the rows.

The district of Latakia, in the northern part of Syria, has long been celebrated for its tobacco, which is the chief product of the mountainous part. There are several kinds:—(1) *Abu Riha* or *Dgebeli*, found in its best state among the mountains of the Nesseries (Ansaries), which possesses a peculiar and much admired aroma, derived from its being exposed, from November to April, to the smoke of fires of *ozer* (*Quercus Ilex*, or *Q. Cerris*); (2) *Dgidar*, including a number of kinds, of medium strength, and in great favour locally on account of its low price; (3) *Scheik-el-Bent*, almost equal to *Abu-Riha*, and often substituted for it.

The plain of Koura is remarkable for its tobaccos, which are rather strong, but much admired. The villages of Lebail and Serai produce better tobacco than Koura. The district of Gebail (Gebel) in Kesrasan (Castravan) affords the best and dearest tobacco in Syria; it is very brittle, and its ash is quite white. The country south of Lebanon yields very ordinary qualities, known as *Salili*, *Tanoné*, and *Takibê*, or generically as *Berraoni*; these are mixed with stronger kinds for use. The best of the *Abu-Riha* is yielded by the plant called *Karn-el-Gazel*; the second quality is termed *Bonati*.

The exports of tobacco from Alexandretta in 1879 were:—To Egypt, 91 tons, value 6380*l.*; Turkey, 24 tons, 1920*l.*; England, 51 tons, 2550*l.*; France, 1 ton, 80*l.* The exports from Aleppo in 1878 were 30 tons, value 1200*l.*, to Great Britain. The yield of the crop in Thessaly was 1,116,000 *okes* (of 2·83 lb.) in 1877, 210,000 in 1878, and 890,000 in 1879. The crop of Prevesa in 1878 was 4000 *okes*, value 215*l.* The exports from Dedeagatch were about 260 bales, value 1000*l.*, in 1878; and 600 bales, value 2400*l.*, in 1879. Considerable quantities are grown around Sinope. Tobacco is one of the principal products of the district of Samsoun, and is of good quality. The average yield is 7,000,000 lb. yearly. It is grown near the sea-shore, and not eastward of Yomurah, at Matchka and Trebizond, and especially at Akché-Abad. But the aggregate crop in these localities is hardly ⅓ of the quantity produced at Samsoun, and the quality is far inferior. The Samsoun product is usually purchased largely on account of the French Government. The exports from Samsoun in 1878 were:—To Turkey, 2,680,000 *kilo.*, value 160,800*l.*; France, 583,500 *kilo.*, 28,008*l.*; Russia, 575,000 *kilo.*, 57,500*l.*; Germany, 400,000 *kilo.*, 7200*l.*; Austria, 327,220 *kilo.*, 31,266*l.* Great Britain, 87,567 *kilo.*, 1576*l.*; total, 4,653,287 *kilo.*, 286,350*l.* The exports of Turkey-produced tobacco from Trebizond in 1879 were:—To Turkey, 14,864 cwt., value 44,592*l.*; Russia, 866 cwt., 2598*l.*; Great Britain, 490 cwt., 1470*l.*; Austria and Germany, 204 cwt., 612*l.*; total, 16,424 cwt., 49,272*l.*

United States.—The United States of America occupy the foremost rank among tobacco-growing countries. The areas and productions have been as follows:—1875, 559,049 acres, 379.347,000 lb.; 1876, 540,457 acres, 381,002,000 lb.; 1877, 720,344 acres, 489,000,000 lb.; 1878, 542,850 acres, 392,546,700 lb. The crop of 1875 (in millions of lb.) was thus contributed:—Kentucky, 130; Virginia, 57; Missouri, 40; Tennessee, 35; Maryland, 22; Pennsylvania, 16; N. Carolina, 14¾; Ohio, 13½; Indiana, 12¾; Connecticut, 10; Massachusetts, 8½; Illinois, 8. The average yields (in lb. per acre) of the various districts in 1875 were:—Connecticut, 1600; Pennsylvania, 1600; New Hampshire, 1600; Massachusetts, 1350; Missouri, 850; Arkansas, 822; New York, 800; Florida, 750; Ohio, 700; W. Virginia, 680; Maryland, 675; Tennessee, 675; Kansas, 670; Texas, 650; Kentucky, 630; Virginia, 630; Illinois, 550; Georgia, 550; N. Carolina, 500; Indiana, 500; Wisconsin, 500; Alabama, 465; Mississippi, 317. The exports from New York in 1878 were:—37,484 hogsheads, 2561 bales, and 2,218,200 lb. manufactured, to Great Britain; 15,570 hh., 207 bales, and 14,800 lb. manufactured, to France; 35,700 hh., 78,331 bales, and 147,400 lb. manufactured, to N. Europe; 23,150 hh., 6058 bales, and 120,000 lb. manufactured, to other Europe; 4628 hh., 14,360 bales, and 4,780,200 lb. manufactured, to S. America, E. and W. Indies, &c.

Baltimore exported 66,039 hh. in 1878. The shipments from New Orleans in 1877–8 were:—1226 hh. to Great Britain, 743 to France, 4552 to N. Europe, 3222 to S. Europe, Mexico, &c., and 4500 coastwise. Philadelphia, in 1879, exported 9,564,171 lb. of leaf tobacco, 52,000 cigars, and 515 lb. of snuff. The total American export of unmanufactured leaf in 1879 was 322,280,000 lb.

W. Indies.—The Spanish possessions in the W. Indies are well known for their tobacco. The best is produced on the *vuelta abajo*, or low-lying districts of Cuba, near Havana, which are yearly flooded during the autumn, just before the tobacco is transplanted. To this fact, and the peculiar suitability of the seasons, the excellence of this particular product is attributed. The exports from Havana in 1878 were:—93,603 bales tobacco, 75,212,268 cigars, 203,581 bundles cigarettes, to the United States; 6169 bales tobacco, 66,795,330 cigars, 5,034,774 bundles cigarettes, to England; 32,582 bales tobacco, 9,541,498 cigars, 133,008 bundles cigarettes, to Spain; 582 bales tobacco, 3,861,700 cigars, 8206 bundles cigarettes, to N. Europe; 5671 bales tobacco, 18,327,025 cigars, 797,513 bundles cigarettes, to France; 41 bales tobacco, 900,850 cigars, 5,709,442 bundles cigarettes, to other countries. The totals for 1878 were 7,078,904 *kilo.* of tobacco, 182,356 thousand cigars, and 12,816,903 packets of cigarettes; in 1879, 6,371,014 *kilo.* of tobacco, 145,885 thousand cigars, and 14,098,693 packets of cigarettes. The tobacco exports in 1879 from St. Jago de Cuba were 9653 bales to Bremen, 4015 to the United States (chiefly for Bremen), and 1809 coastwise, total 15,477, against 10,249 in 1878. In the island of Puerto Rico, the tobacco-plant thrives well, and the quality, especially in the Rio de la Plata district, is very good. In 1878, the island exported 8 *quintals* (of 101½ lb.) to the United States, 32,109 to Spain, 4198 to Germany, and 18,123 to other countries.

The British W. Indies have only recently appreciated the importance of tobacco cultivation. Many portions of Jamaica seem as well fitted for it as the *vuelta abajo* of Cuba, and already Jamaica tobacco in the Hamburg market ranks next to the best Havana, and is considered superior to such Cuban growths as St. Jago, Manzanillo, Yara, &c. Tobacco-cultivation may now be said to have a place in the industries of Jamaica, a fact mainly due to Cuban refugees. The most extensive plantations in the island are Potosi in St. Thomas Parish, and Morgan's Valley in Clarendon. Much of the produce goes to the German market, the remainder being made into cigars for local consumption, and said to be quite equal to some of the best Cuban brands. Some experiments made with Bhilsa tobacco have given great satisfaction, on account of the robust habit and immense yield of the plant. It is especially adapted for very wet districts, and its cultivation will be widely extended, if justified by its market value. Tobacco is, and for very many years has been, grown by the peasantry in small patches; from this, they manufacture a smoke-dried leaf, which, twisted together in rope form, sells readily in the home market. The acreage occupied by the crop was 297 in 1874–5, 442 in 1875–6, 331 in 1876–7, and 380 in 1877–8. The slopes of valleys in many parts of Dominica, too, are eminently suited to this crop, particularly the district between Roseau and Grand Bay. The experiment of tobacco-culture in New Providence on a large scale has not proved satisfactory, owing to the difficulties encountered in curing and preparing the leaf; the cigars made are fit only for local consumption.

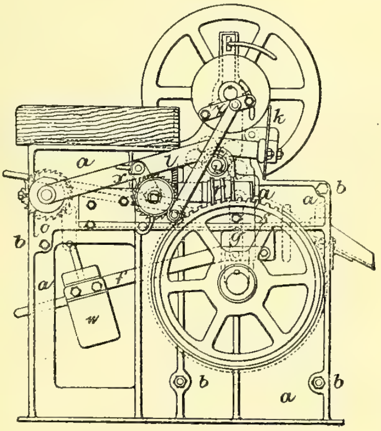
Preparation and Use. Manufacture of Cut-, Cake-, and Roll-tobacco; Cigars, Cigarettes, and Snuff.—It is impossible to indicate the precise form in which each kind of tobacco-leaf is manufactured for use; indeed, no well-defined line marks the qualifications of each sort, and the great art of the manufacturer is to combine the various growths in a manner to produce an article suited to the tastes of his customers, at a price suited to their pockets. But, in a general way, it may be said that Havana and Manilla are probably exclusively consumed in the form of cigars; Virginia is a favourite for cavendish, negrohead, and black twist, and is largely converted into returns, shag, and snuff; Kentucky, Missouri, and Ohio are used for cavendish, brown twist, bird's-eye, returns, and shag; Dutch and German make the commonest cigars, k'naster, moist snuffs, and smoking-mixtures; Java and Japan are selected for light cigars, mixtures, and light moist shag; Latakia, Turkey, Paraguay, Brazil, China, and the remainder, are used up in cigarettes, mixtures, imitations, and substitutes.

Damping.—The tobacco-leaves are received by the manufacturer in all kinds of packages, from a hogshead to a seron (raw hide), and of all weights from 1 to 12 cwt. The first process they undergo is "damping," which is necessary to overcome their brittleness, and admit of their manipulation without breaking. For this purpose, the bunches ("hands") are separated, and the leaves are scattered loosely upon a portion of the floor of the factory, recessed to retain the moisture. A quantity of water, which has been accurately proportioned to the absorbing qualities of the leaf used, and to the weight present, is applied through a fine-rosed watering-pot, and the mass is left usually for about 24 hours, that damped on one morning being ready for working on the following morning. In England, water alone is admissible (by legislative enactment) for damping, except in special cases to be noted subsequently; but abroad, many "sauces" are in vogue, their chief ingredients being salt, sal ammoniac, and sugar.

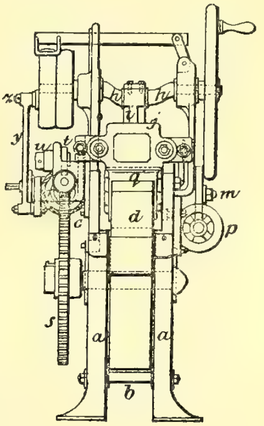
Stripping and Sorting.—Quantities of leaf-tobacco are shipped in a condition deprived of their stem and midrib, and are then known as "stripts." Those which are not received in this state, after having been damped, are passed through the hands of workmen, who fold each leaf edge to edge, and rip out the midrib by a deft twirl of the fingers, classifying the two halves of each leaf, and ranging the sorts in separate piles as smooth as possible. The value of the leaf greatly depends upon the dexterity with which the stripping is done, as the slightest tear deteriorates it. Stripts require sorting only. The largest and strongest leaves are selected for cutting and spinning; the best-shaped are reserved for the wrappers of cigars; broken and defective pieces form fillers for cigars; and the ribs are ground to make snuff. For the manufacture of "bird's-eye" smoking-tobacco, the leaves are used without being previously stripped.

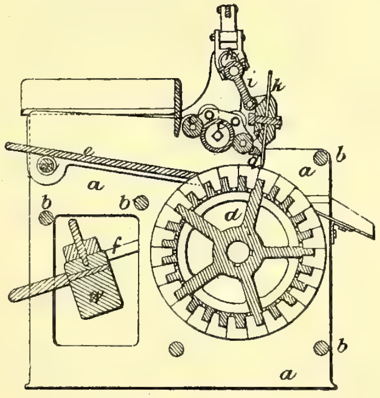
Cutting.—Cutting is the process by which the damped leaves, whether stripped or not, are most extensively prepared for smoking in pipes and cigarettes. The tobacco-cutter which is in general use in this country is shown in Figs. 1001 (side elevation), 1002 (sectional elevation), 1003 (front elevation), and 1004 (plan). The main frames *a* are united by stretcher-bolts *b*; *d* is a wooden-surface feeding-roller, on which the tobacco is pressed and cut; *c* are the upper compressing- and feeding-rollers, mounted in *e*, carriage-plates extended backwards, forming the sides of the feeding-trough, and hinged to the axle *m*; *f* are levers; *g*, links by which the weight *w* presses down the upper rollers; *h*, a crank, and *i*, a connecting-link for working; *j*, the cross-head to which the knife *k* is fixed; *l*, side-levers or radius-bars for guiding the knife, hinged on the eccentric ends of the axle; *m*, an axle held in bearings at the back of the machine; on its middle part, which is concentric with its own bearings, are hinged the top roll carriage-plates *e*, whilst on its projecting ends, which are slightly eccentric, the knife-levers *l* are hinged; *n* is a worm-wheel segment; *o*, a worm; *p*, a hand-wheel for turning the eccentric spindle *m* through a part of a revolution in its bearings, for adjusting the contact of the knife with the nose-plate *q*; *r*, a worm; *s*, a worm-wheel; *t*, a worm-pinion for giving simultaneous movement to all the rollers; *u*, a spindle, "universal jointed" at both ends, for driving the upper rollers in positions varying with the thickness of the feed; *v*, a saw-toothed ratchet-wheel, moved intermittently by a catch *x*, link *y*, and stud-pin *z*, *v* being changeable, and the eccentricity of *z* variable, for the purpose of regulating the fineness of the cutting. Both ends of the knife move at the same speed, and its surface is made to clear the work by describing a slight curve. The knife is adjusted accurately to the nose-plate, while the machine is in motion, by varying the direction of eccentricity of the axis of the knife-levers to that of the roller-levers. The fineness of the cutting is regulated by varying the eccentricity of a movable stud-pin in a plate on the crank-shaft which gives motion, through a train of speed-reducing gear, to the several rollers. The

1001.



1003.





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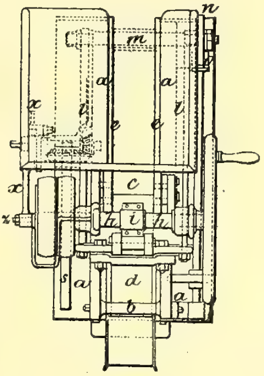


1004.

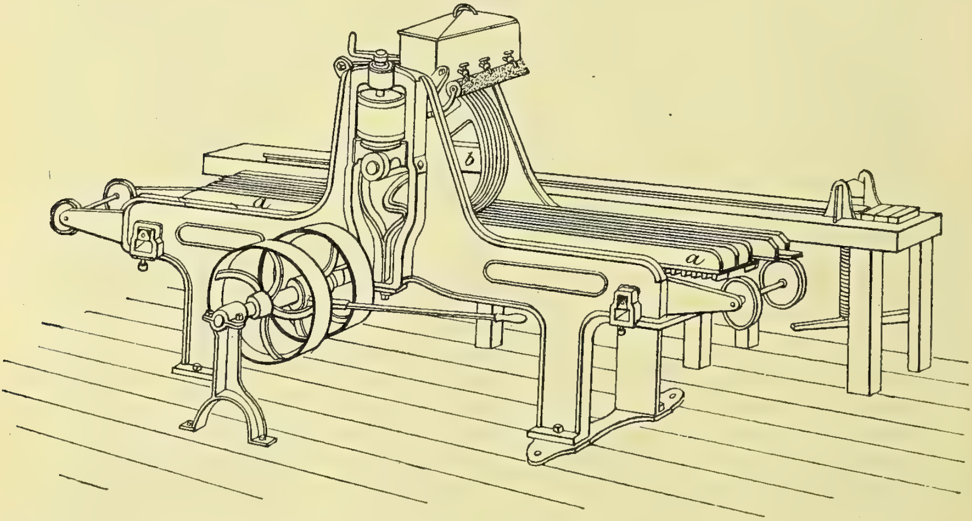
knives are easily removed and replaced, and require sharpening after every 4–6 hours' working. Two men attend the machine, one to keep the feed-rollers supplied, the other to watch that the knife is doing its work, and to remove the tobacco as fast as it is cut.

Drying.—The cut tobacco, as removed from the machine, is placed loosely in a layer several inches deep in a large trough, provided with a canvas false bottom; steam is introduced between the true and false bottoms, and finds its way up through the tobacco, which is thus rendered more easily workable. It is next transferred to a similar trough having no false bottom, but a steam-jacketed floor instead; here the tobacco is dry-heated, and at the same time lightened up by hand. Finally, it is taken to a third trough, where cold air is forced through the canvas false bottom, by means of a blower or fan. This last operation dries the tobacco ready for use in the course of some hours; but it has the disadvantage of dispersing part of the aroma, and is therefore generally resorted to only when time presses. In other cases, the drying is conducted on canvas trays. However performed, the drying operation needs the greatest attention, to prevent the moisture being extracted to such a degree as to destroy the profit which its presence confers upon the manufacturer. With drying, the preparation of cut tobacco for smoking in pipes is completed.

Cake or Plug.—The manufacture of "cake" or "plug" is little carried on in this country, as the Excise laws exclude the use of sweetening matters, except when carried on in bond. The process is sufficiently simple. Virginian leaf, with or without the addition of flavourings, is sweated for a day or two, to deepen the colour, worked into a soft mass, and next placed in moulds, and subjected to sufficient pressure to ensure the cohesion of the mass. Each cake is then separately wrapped in perfect leaf, and passes through a series of moulds, each smaller than the last, and under increasing pressure in steam-jacketed cupboard-presses, of which there are many forms. The combined effect of the heat and pressure is to thoroughly impregnate the whole mass with the natural juices of the leaf and the flavouring (if any has been used), and to produce a rich dark colour.

A machine for turning out plug-tobacco in ribbons, made by the McGowan Pump Co., New York, is shown in Fig. 1005. The tobacco is first weighed out in the proper quantities, and spread in a box placed in spaces in a heavy iron table *a*. When the latter is filled, it is passed to and fro under the heavy iron wheels *b*, which are loose on the shaft, and which can be adjusted to exert any desired pressure. Twice passing through suffices. The ribbon is made in lengths of 10 ft., and either $5\frac{3}{4}$ in. or $2\frac{7}{8}$ in. wide, as desired.

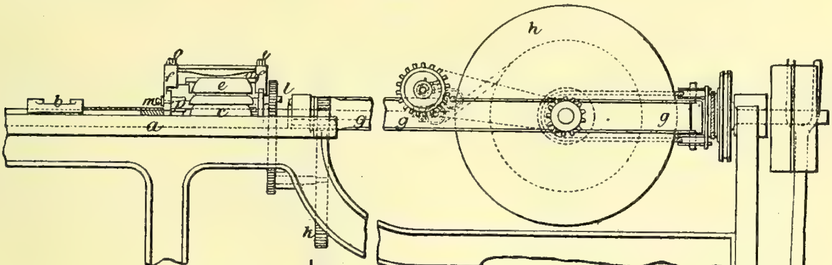
1005.

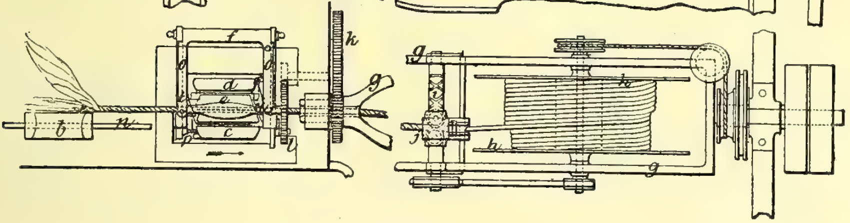


Roll or Twist.—Roll- or twist-tobacco is made by spinning the leaf into a rope, and then subjecting it to hot pressure. Until recently, the spinning was performed by hand, much after the manner of ordinary rope-making by hand. But this slow process is now superseded by a machine made by Robinson and Andrew, of Stockport; it is spoken of in very favourable terms by English manufacturers, and received a diploma of merit at the Philadelphia Exhibition. The machine consists of a combination of 3 rollers, whose surfaces are made of segments, to which lateral to-and-fro motions are given by cams attached to the stands on which the axles of the rollers rotate. The tobacco occupies the central space between the 3 rollers, and it is carried through the machine by the lateral to-and-fro motions given to the segments. The fillers and wrappers are laid on a table joined to the machine. The filler is placed in the cover, and they pass together between the rollers, whose action twists and compresses the tobacco into a roll; this is carried forward and wound on a bobbin, revolving in an open frame, and provided with a guide for equalizing the distribution of the tobacco.

The machine is shown in Figs. 1006 (elevation), 1007 (plan), and 1008 (end view). The tobacco is laid on the table *a*, provided with a rib *n*, on which the sliding rest *b* is free to move to and fro; *c d* are the two lower segmental rollers, the axles of which revolve in stationary bearings; *e* is the top roller, the axle of which revolves in sliding bearings, fitting in the swing-frame *f*, and each acted upon by a spring *o*, pressing on a pin communicating with the bearing, and putting an elastic pressure on the tobacco.

1006.

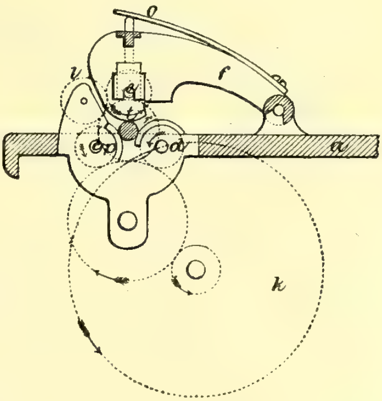




1007.

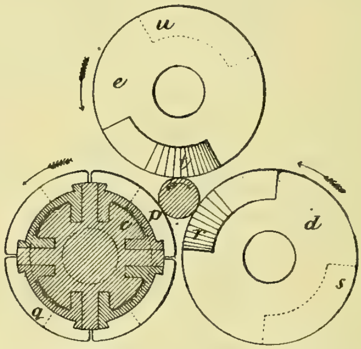
Each segment-roller consists of an axle with four segments, best shown in Figs. 1009 and 1010. The outer shell of the segments is made of hard wood, fitting an inner shell of malleable cast-iron, the projections on which suit grooves on the cast-iron axle. The segments of the rollers *c d* are moved laterally to and fro by the wedge-shaped cams *p q r s*, fixed to the bearings of the roller-axles; and the segments of the roller *e* are moved in the same manner by cams *t u*, fixed to the swing-frame *f*. The tobacco occupies the central space between the 3 rollers, and the cams *p r t* move the segments in the direction of the arrow where they touch the tobacco, while the cams *q s u* move them back. After the tobacco has passed beyond the segment-rollers, it goes through the hollow trunnion of the open frame *g*, in which the bobbin *h* revolves; the other trunnion of the frame *g* is provided with fast and loose pulleys, by which the whole machine is driven. To this trunnion, are also fixed an ordinary friction-break pulley, and a grooved pulley, around which latter passes a band for driving the pulley on the axle of the bobbin *h*. To the other end of the axle of the bobbin, is fixed a pinion, which, by means of a toothed chain, gives motion to another pinion fixed to the double screw *i*; this double screw gives a traversing to-and-fro motion to the guide *j*, for distributing the tobacco evenly on the bobbin, by means of a swivel T-headed stud, connected with the guide, and taking into the thread of the double screw. The guide is provided with two horizontal grooved rollers, between which the tobacco passes, and with two other rollers to guide the tobacco on to the bobbin.

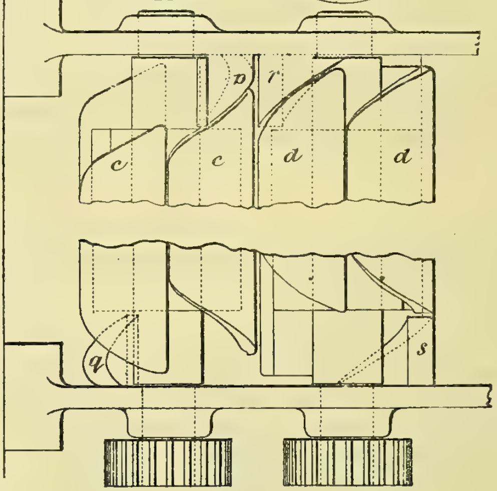
1008.



Rotary motion is communicated to the segment-rollers *c d e* as follows:—To the hollow trunnion of the open frame *g*, is affixed a pinion, which drives the wheel *k*, on the same shaft as the change-pinion that drives the wheel gearing into the pinions on the axles of the rollers *c* and *d*, and one of which pinions gears into the intermediate pinion *l*, which drives the pinions on the axle of the roller *e*. The driving strap is held upon the fast pulley by a drop-catch acting on a weighted lever, one arm of which is connected by a link to the lower end of a strap fork-lever. When it is requisite to stop the machine, the attendant kicks the point of a catch off the end of the lever, which is then raised by the weight, and so moves the driving-strap from the fast to the loose pulley, the stoppage being virtually instantaneous. The mode of working is as follows:—The spinner and assistants stand at opposite sides of the table; the fillers and wrappers being placed on the table, one assistant spreads out the wrapper and pushes the end towards the filler, which the spinner supplies and holds against the sliding rest *b*; the rotary motion of the segment-rollers *c d e* twists the tobacco, and causes the wrapper to be wound over the filler, and the rest *b*, being movable, enables the spinner to regulate its position according to the quantity and quality of the filler and wrapper. The lateral motion of the segment-rollers passes the roll towards the bobbin, on which it is wound, as described. The combined rotary and traversing motions of the rollers consolidate the tobacco, and put the desired face upon the twist. The roller *e* is supported in a swing-frame, which is lifted off the tobacco when starting the machine. When the machine is at work, the swing-frame is held down by the stud *m* (Fig. 1006). The figures represent a machine suitable for manufacturing Limerick roll; for pigtail and other small descriptions, it is necessary to reduce the diameter of one or more of the segment-rollers.

1009.





1010.

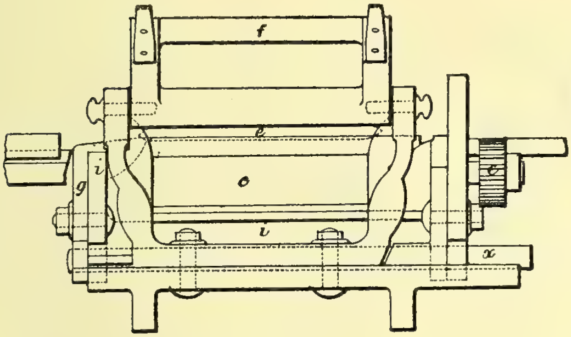
A more recent improvement in this machine, by J. E. A. Andrew, is shown in Figs. 1011 (side view), 1012 (transverse section), and 1013 (plan). The table *a*, rib *n*, and sliding-rest *b*, and two lower segment-rollers *c d*, are constructed as usual; but the axles of the segment-rollers revolve in bearings *g h*, bolted to the flanges of swivel-frames *i k*, hinged upon the fulcrum-shaft *x*; the object of thus supporting the bottom rollers *c d* is to be able to vary the distance between them according to the thickness of the twist of tobacco that is being rolled. When the distance between the rollers is fixed, the bearings are secured by bolts passing through segmental slots. The solid top roller *e* revolves in centres in sliding bearings fitting in the swing-frame *f*.

As the bobbin is filled, it is removed, and replaced by an empty one. The rope is then unwound, and formed into rolls, by the aid of a spindle with flanges at the sides, worked by a treadle, under a cushioned weight which squeezes the coils closely together as they are wound. The completed rolls are subjected to great pressure in steam-jacketed presses, in the same way, and with the same object, as the cakes or plugs.

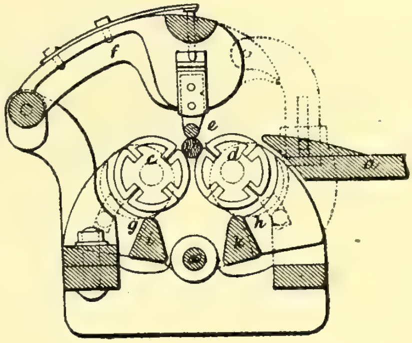
Cigars.—Cigars are composed of two parts, a core formed of pieces of leaf placed longitudinally, known as "fillers," and a covering formed of perfect leaf, called the "wrapper." Probably all the best cigars are made by hand, the only tools required being a short-bladed sharp knife, a receptacle containing an emulsion of gum, and a square wooden disc or "cutting-board." A portion of perfect leaf is first shaped to form the wrapper of the cigar; then a bunch of fillers is moulded in the hand, and rolled up tightly in the wrapper, the taper end being secured by gumming. Expert workmen make the cigars remarkably uniform in weight and shape. When made, they are sorted according to colour, deftly trimmed at the thick end, and placed in their boxes in cupboards heated by gas-stoves to finally dry or season before being stored for sale.

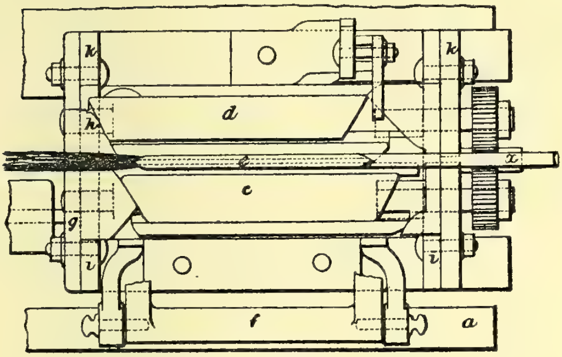
In America, machinery is introduced wherever possible. Moulds for shaping the cigars are made of hard wood, sometimes partially lined with tin, and of every possible size and form. A machine is made by Dubrul and Co., of Cincinnati, for working 3 sets of moulds at once, 2 being kept filled up under pressure while the 3rd is being filled, or the bunches are being rolled up. A handy little machine for rolling the fillers for cigars is that known as Henneman's, made by Dubrul and Co. The demand for scrap-made cigars, or those manufactured with short fillers, has caused the introduction of machines for cutting and sifting scrap. One made by Dubrul and Co. is shown in Fig. 1014. It consists essentially of a cylinder formed of hook-shaped, double-edged steel blades, revolving against 3 series of fixed but adjustable steel blades, thus permitting the size to be regulated at will.

1011.



1012.





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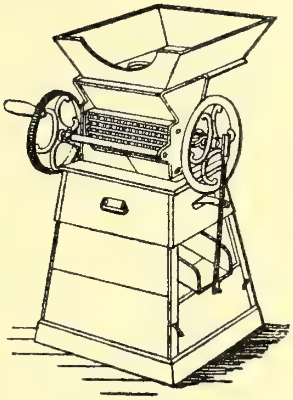


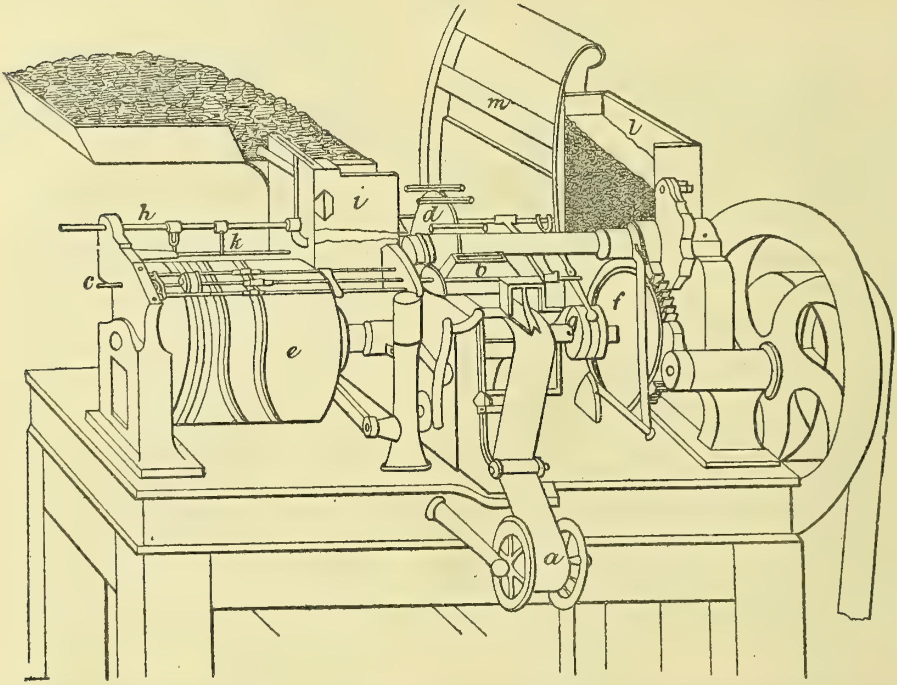
1014.

Cigarettes.—Cigarettes consist of paper tubes filled with cut tobacco, with or without an external wrapper of leaf tobacco. Preference is usually given to those made by hand, but machines have been introduced with some success for making the commoner kinds. A French machine for making cigarettes is shown in Fig. 1015. Its work consists in making the paper tubes, and filling them with tobacco. The paper, previously prepared, in a band about 3 in. wide, is unrolled from the coil *a* by means of the carriage *b*, and cut off in pieces about 1 in. long for presentation to the mandrel *c*, temporarily introduced into one of the tubes of the mould-carrier *d*. The mandrel has a clamp which grasps the paper and rolls it, and, at the moment when the latter escapes from the carriage, its free end is brought upon a rubber pad covered with gum, hidden in the illustration. The paper tube is left in the mould, the mandrel being extracted by means of the cam *e*; the mould-carrier is then turned $\frac{1}{6}$ rev. by the cam *f*, a new tube comes into line, and the operation is repeated. When 6 paper tubes are completed, the first one is pushed by a small piston, actuated by the cam *g*, upon the end of the filling-tube; and immediately the rod *h*, actuated by the cam *e*, drives into this tube a portion of tobacco already prepared in the compressor *i*. In preparing the tobacco, a workman, occupying the seat *m*, is necessary to dispose the material in regular layers on a carrier, by which it is transported into the compressor. When the cigarette-envelope is filled, the mould-carrier again makes part of a revolution, and the finished cigarette is pushed out of the mould by the rod *k*, also actuated by the cam *e*; a device finally lodges the cigarettes in the box *l*.

One workman is said to be able to turn out 9600 cigarettes in 10 hours by the aid of the machine.

Snuff.—Snuff is entitled to the last place in the series of tobacco manufactures, as it is largely made up of the scraps, cuttings, and rejections of the preceding processes. The materials are chopped very fine, placed in heaps in warm damp cellars, "doctored" with various flavourings, left to ferment for several weeks, and then ground to powder in edge-runner mills, some kinds even undergoing a slight roasting. When ground, the mass is passed through "mulls," wood-lined, bottomless bowls, let into a bench, where the snuff is softened and rendered less powdery by means of pointed pins, resembling domestic rolling-pins, which slowly travel around the sides of the bowls. Snuff represents a highly profitable article manufactured from materials that are otherwise useless, and depending for its favour chiefly upon the perfumes and flavourings used. Hence these last are kept profoundly secret by the manufacturer.

1015.



From refuse tobacco which is unfit for any other purpose, is made a decoction for washing sheep and destroying vermin; often the waste is ground very fine, and used by gardeners, presumably to keep noxious insects away.

Miscellaneous Appliances.—The customary ingenuity of the Americans has invented a profusion of admirable labour-saving machines for almost all the operations of the tobacco-manufacturer. A few of these only can be noticed in the present article.

Fig. 1016 shows a portable resweating-apparatus, intended for darkening the colour of tobacco to suit the dealer's market. It measures 4 ft. long, 3 ft. wide, and 5 ft. high, being just large enough for one case (400 lb.) of tobacco, including the case; it consists of a water-tank *a*, a pipe *b* for conducting the water into the metallic pan *c* at the bottom of the apparatus, which is heated by gas-jets *d*. The tobacco is introduced by the door *e*, which is fitted with a thermometer. The roof is sloped so as to determine the flow of the water of condensation. The steaming occupies 3–5 days, and needs occasional watching. The apparatus is made by C. S. Philips and Co., 188 Pearl Street, New York.

1016.

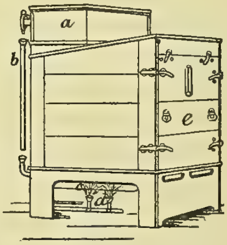
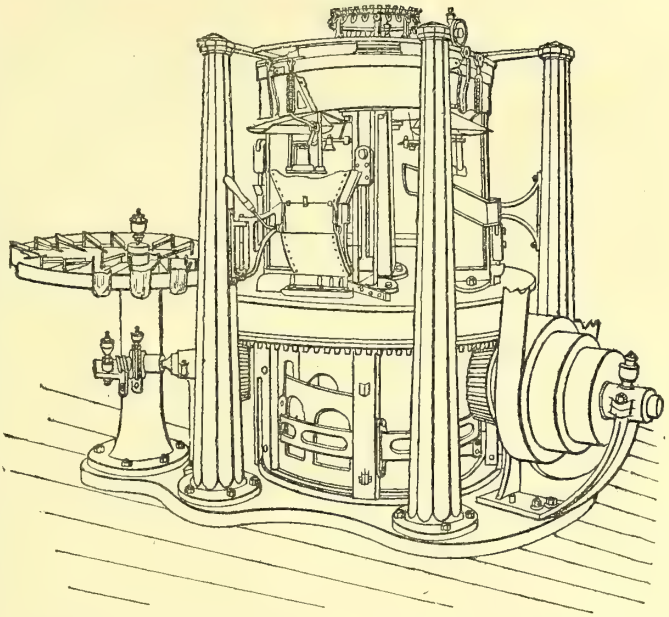


Fig. 1017 illustrates a complicated machine, introduced by C. C. Clawson and Co., of Raleigh, N. Carolina, for putting up large quantities of tobacco in parcels of 2 oz. upwards. It consists of a central table provided with automatic scales for weighing out the portion; four equidistant guides which determine the form of the package; a plunger for packing, and a follower for raising the package; a side-table carrying tongs for holding the empty bags; and another to receive the packages, and hold them during tying. The hopper being supplied with tobacco, and the machine put in motion, each form takes a bag from the tong-table, and the article having been weighed, is carried to the form by a shute, when it drops into the bag, is packed by the plunger, and transferred to the tying-table. With 2 girls or boys, it is said to weigh, pack, and tie 30 bags a minute.

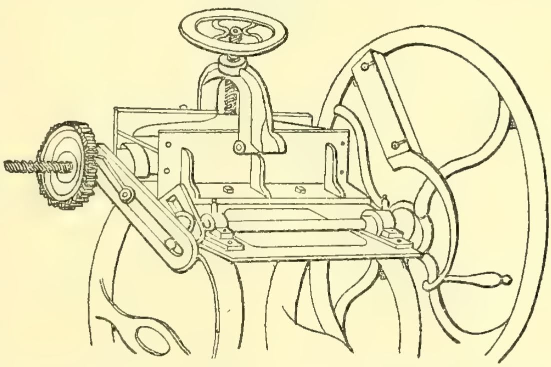
1017.



The New York Tobacco Machine Co. make two forms of machines for granulating tobacco, chiefly for making "Killickinick" and cigarettes, their working capacity ranging from 200 to 2000 lb. a day. The cutting-rollers are covered with cross-millings at right angles to each other, those running lengthwise being deep; the fixed cutters are adjustable, so that the cutting may be either coarse or fine. When working, the action is like that of a pair of shears, except that the cross-millings reduce the strips to a granular state. Both stems and leaves may be worked up. The great advantage claimed for these machines is that, though the tobacco should be dry, the percentage of dust escaping is reduced to a nominal figure.

A cutting-machine made by the same Co. is shown in Fig. 1018. It is adapted to cut leaf, stem, scrap, plug, or any form of tobacco, to any required degree of fineness, turning out 300–400 lb. a day. The action is almost precisely that of a chaff-cutter. The Co's. sifting-machine consists of an adjustable cylindrical wire sieve, with a rattan-broom screw-roller revolving inside. The stems are stripped and worked out at one end, while the remainder is broken up, and passed through the sieve, falling upon a perforated tray, through which pass the finest particles for snuff-making. A machine largely used in America is the stem-roller, for crushing and flattening the stems so that they may be used like leaves for making cigars. Great benefit is anticipated in the United States from the adaptation of Ryerson's "attrition mill" to snuff-grinding, owing to the fact that the pulverization is accomplished without the particles being heated in the least degree. Of cigarette-making machines, there are many kinds; the best are those which deal with the tobacco in a comparatively dry state, thus preventing shrinkage after packing.

1018.



Indebtedness is acknowledged to Hy. Archer and Co., Borough, S.E., and T. Brankston and Co., Carter Lane, Doctors' Commons, for opportunities of inspecting their thoroughly representative works, and for much information readily given concerning the manufacture in this country; to W. Jollyman, of W. D. and H. O. Wills' London house, for having revised these sheets before going to press; and to Hy. A. Forrest, 61 Broadway, agent of the New York Tobacco Machine Co., for valuable material relating to American machines and processes.

Nature and Properties.—The active principle of tobacco is a volatile, highly poisonous alkaloid, called Nicotine ($C_{10}H_{14}N_2$). Although green tobacco-plants contain generally more nicotine than the leaves after they have been prepared for the market, yet the odour is only perceptible after the fermentation of the leaves has set in. It has been ascertained that young leaves 2 in. long contained 2·8 per cent., and leaves 10½ in. broad and 16 in. long, as much as 5·6 per cent. of their weight of nicotine. The amount increases as the plants become ripe, and decreases on their becoming overripe.

Though the narcotic effects of tobacco experienced by the smoker must partly be attributed to nicotine, it cannot be said that they are solely due to it. It is well known that the products of combustion of quite harmless substances are often stupefying. Good Syrian tobacco contains no nicotine, yet smokers consider cigars made from this tobacco to be strong. It is evident that the strength of a cigar, as judged by the smoker, depends greatly on the circumstance whether the tobacco burns well or not. If it burns well, a greater amount of nicotine is consumed and decomposed, and less of the narcotic products of combustion are created, than when it burns badly. Cigars of the latter description, containing little nicotine, are more narcotic in their effects when smoked than well-burning cigars containing much nicotine.

The amount of nicotine in tobacco varies very much, according to the sort of plant, the climate, the nature of the soil in which the plant grew, the treatment received during its growth, and the course adopted to prepare the leaf for the market. Dr. Nessler found that good Syrian tobacco contained no nicotine, Havana tobaccos between 0·6 and 2·0 per cent., and German tobaccos between 0·7 and 3·3 per cent. Schlösing found in French tobacco nearly 8·0 per cent. of nicotine. Fine tobaccos contain generally little or no nicotine. Broughton found that the amount of nicotine in Indian tobaccos varies very much. The conditions favourable to the development of nicotine in the plants are:—Soil in a bad physical state, strong nitrogenous manure, a dry atmosphere, and probably a low temperature during the growth.

According to Nessler, green and newly-cut tobacco-plants contain no ammonia; it is developed during the drying and fermentation of the leaves, especially when they assume a brown colour. Tobacco-leaves, which have undergone a strong fermentation, contain more ammonia than those slightly fermented. Fine tobaccos contain generally less ammonia than coarser ones. In various smoking-tobaccos, Nessler found:—Havana, 0·2 per cent. of ammonia; Cuba, 0·3; Syrian, 0·6; German, 0·9 per cent.. Schlösing found Havana tobacco to contain 0·8 per cent.

Nitric acid, consisting of nitrogen and oxygen, is formed in animal and plant substances when decomposed under the influence of atmospheric air and a sufficiently high temperature; whereas ammonia, consisting of nitrogen and hydrogen, is formed when those substances decompose in the absence, or nearly so, of atmospheric air. Organic substances decomposing under the latter condition emit an objectionable pungent odour, which must partly be attributed to the formation of ammonia. Tobacco, soon after harvesting, commences, according to the conditions under which it is placed, one of these decompositions. The extent of the decomposition the tobacco has gone through may be partly judged from the colour the leaves have attained. If leaves be dried so rapidly as to remain green, the decomposition is probably confined to the formation of carbonic acid. A yellow colour indicates the formation of nitric acid; and a dark-brown or black colour, that of ammonia. The conditions under which nitric acid and ammonia are formed being known, it is possible to control their development. When the tobacco is hung far apart, so that the air has free access, the formation of nitric acid will take place; but if the air be excluded more or less, by hanging the tobacco very close, or pressing it in heaps or pits, the formation of ammonia is engendered.

Nitric acid generally promotes the combustion of plant substances, by supplying a portion of the needed oxygen, and has undoubtedly a similar effect in tobacco; its occurrence in the tobacco is therefore a desideratum with the cultivator and manufacturer, and to supply any deficiency, the manufacturer often resorts to impregnating his tobacco with a solution of saltpetre. From this, however, it must not be concluded that every tobacco containing a large amount of nitric acid will necessarily burn well. Schlösing and Nessler have shown that the well-burning of a tobacco does not always correspond with a great amount of nitric acid, thus indicating that other substances or other conditions also affect the combustibility. The effect of the nitric acid will most probably vary with the base with which it is in combination.

The nitrogen in the forms of nicotine, ammonia, and nitric acid, constitutes only a small portion of the total amount present in tobacco; by far the greater portion ($\frac{5}{8}$–$\frac{7}{8}$) exists in the form of albuminoids. Nessler found that the nitrogen under this form varies from 2 to 4 per cent., which is equal to 13–26 per cent. of albuminoids. Substances rich in albuminoids generally burn badly, and emit a pungent noxious odour. On the condition of these albuminoids, and on the presence of other substances, as nitric acid, alkalies, &c., in the tobacco, mostly depend the burning qualities of the leaf, and the flavour of a cigar. The Eastern habit in smoking, from Malaysia, Japan and China, through India, Persia and Turkey, even to Hungary, is to inhale the smoke into the lungs, and natives of these countries maintain that a tobacco should be of full flavour without burning the throat or catching the breath. Western nations do not admit the smoke further than the mouth, and therefore require a strong, rank flavour.

Whilst drying and fermenting, the tobacco undergoes great changes. Some substances are decomposed, others are newly formed. The highly complicated compounds, the albuminoids, undergo first decomposition, and in doing so give rise to more simple combinations. Nitric acid, ammonia, and other substances less known are chiefly, if not entirely, derived from the products of the decomposition of albuminoids. The substances that cause the objectionable pungent smell in tobacco are formed from the broken-up constituents of these high combinations. The conditions under which these bad-smelling combinations originate are not properly known; but it is probable that they are developed with, and under the same conditions that cause the formation of, ammonia, as the disagreeable pungent flavour is found generally in tobacco that has undergone fermentation to a great extent. It is believed that the conditions that favour the development of nicotine are also conducive to the formation of albuminous substances in the leaf, viz. fresh nitrogenous manure, bad physical state of the soil, &c.

According to Nessler, the quality of tobacco depends to a great degree on the amount of cellulose it contains. He found that a good tobacco invariably contained more than a bad one, Havana yielding as much as 46 per cent. The fact that tobacco burns better after being stored for a time may be partly due to an increase of cellulose in it.

Every tobacco contains more or less fat, gum, ethereal oil, &c. It is not properly known in what way fatty matters affect the quality of tobacco. Many other organic matters exist in tobacco in combination with substances from which it is most difficult to separate them; they have not as yet been quantitatively ascertained, and are therefore little known. Most of them are only developed during the drying and fermenting of the leaf; their presence, however, considerably affects the quality of the tobacco.

The amount of ash constituents in the tobacco is considerable, varying between 16 and 28 per cent. There cannot be said to exist a definite relation between the total amount of ash in the tobacco and its quality, as tobaccos yielding much ash are sometimes of good, and at other times of bad, quality: a good tobacco may yield much or little ash. The relative proportion in which the ash constituents exist is, however, of the greatest importance. It has been ascertained that the presence of some special mineral elements modify to a great extent the quality of the tobacco. Of all ash constituents, potash (K_2O), more correctly speaking potassium carbonate (K_2CO_3), affects the quality of tobacco in the highest degree. Schlösing has pointed out that the good burning qualities of a tobacco depend on the presence in it of potash in combination with a vegetable acid; that a soil deficient in potash is unfit to produce tobacco of good quality. Numerous analyses have tended not only to corroborate the assertion made by Schlösing, but to demonstrate also, that it is not the total amount of potash, but the potash found as a carbonate, which existed in the plant in combination with a vegetable acid, that is the constituent chiefly affecting the combustibility of a tobacco. The complete analyses of Nessler have shown that, although a tobacco may contain a great amount of potash, it does not necessarily follow that the tobacco burns well. He found that some German tobaccos contained more potash than Havana, although the latter burned much better than the former; and that a great amount of potash did not always indicate a great amount of carbonate of potash. Although tobaccos yielding a great amount of carbonate of potash in their ash generally burn well, there may be conditions which neutralize the good effect of this combination, as a large proportion of albuminoids. It may therefore be said that the combustibility of a tobacco is improved in proportion as its ash yields more carbonate of potash, other conditions being equal.

Among the minor salts, the chlorides deserve most attention. It has been found that they generally retard the burning of tobacco, and that as they increase, carbonate of potash decreases. Lime is invariably found more or less in the ash, but it has not been ascertained to what extent its presence affects the quality of the tobacco; good tobacco may contain much or little, so that its presence is probably not of great importance. The same may be said of soda, magnesia, and phosphoric acid. According to Nessler, their proportions may vary thus:—Potash, 1·95–5 per cent.; lime, 6·5–9·2; soda, 0–1·63; magnesia, 0·12–0·99; phosphoric acid, 0·57–1·39.

In connection with the chemistry of tobacco, and the rational manuring of the crop, the name of Prof. S. W. Johnson, Chemist to the Connecticut State Board of Agriculture, must be placed in the foremost rank. Indebtedness is acknowledged to Prof. Johnson for a copy of his valuable report, quoted in the Bibliography at the end of this article.

Adulteration and Substitutes.—It is said that in Thuringia, over 1000 tons yearly of dried beetroot-leaves are passed off as tobacco. These leaves, and those of chicory and cabbage, are similarly employed in Magdeburg and the Palatinate. Many of the *Vevey* cigars of S. Germany are entirely composed of cabbage- and beetroot-leaves which have been steeped in tobacco-water for a long time. Other leaves, such as rhubarb, dock, burdock, and coltsfoot are also used. These are all principally for cigars. For smoking-tobacco, chamomile flowers, exhausted in water, then dyed and sweetened with logwood and liquorice, and dried, have been mixed with tobacco in such proportions as 70–80 per cent. In America, a specially-prepared brown paper, saturated with the juice expressed from tobacco-stems and other refuse, is most extensively used, not only for the "wrappers" of cigars, but also for "filling." Various ground woods, starches, meals, and pigments are introduced into snuff.

Imports, Duties, and Values.—Our imports of tobacco in 1879 were as follows:—

(*a*) Unmanufactured: From United States, 25,743,880 lb., value 682,253*l.*; Holland, 6,215,930 lb., 266,109*l.*; China, 1,444,192 lb., 36,265*l.*; Turkey, 1,214,319 lb., 32,627*l.*; Japan, 805,928 lb., 21,003*l.*; France, 651,350 lb., 14,585*l.*; Belgium, 515,009 lb., 15,501*l.*; Argentine Republic, 470,309 lb., 10,870*l.*; Germany, 426,139 lb., 25,602*l.*; Straits Settlements, 267,258 lb., 29,718*l.*; British India, 246,305 lb., 3605*l.*; New Granada, 241,638 lb., 9621*l.*; Canada, 121,920 lb., 3473*l.*; other countries, 497,043 lb., 14,256*l.*; total, 38,861,220 lb., 1,165,488*l.*

(*b*) Snuff: From all countries, 7719 lb., value 92*l.*

(*c*) Cigars: From Spanish W. Indies, 495,518 lb., value, 494,974*l.*; Germany, 150,460 lb., 46,318*l.*; Holland, 116,218 lb., 31,348*l.*; Philippines, 80,199 lb., 21,738*l.*; France, 73,348 lb., 24,071*l.*; Straits Settlements, 51,191 lb., 13,822*l.*; China, 48,762 lb., 11,240*l.*; Belgium, 46,536 lb., 14,211*l.*; British India, 33,208 lb., 10,898*l.*; United States, 14,625 lb., 5461*l.*; other countries, 43,978 lb., 19,184*l.*; total, 1,154,043 lb., 693,265*l.*

(*d*) Cavendish or Negrohead: From United States, 2,247,557 lb., value 84,422*l.*; other countries, 45,052 lb., 1964*l*; total, 2,292,609 lb., 86,386*l.*

(*e*) Cavendish, manufactured in bond: 33,069 lb., 7126*l.*

(*f*) Other sorts, including cigarettes: From United States, 52,206 lb., value 7999*l.*; Holland, 25,273 lb., 1372*l.*; Channel Islands, 15,470 lb., 1279*l.*; Germany, 14,474 lb., 4472*l.*; France, 9497 lb., 2368*l*; Belgium, 7939 lb., 2086*l.*; other countries, 12,328 lb., 3845*l.*; total, 137,187 lb., 23,421*l.*

The duties on unmanufactured tobacco are 3*s.* 6*d.* a lb. when it contains 10 per cent. or more of moisture; 3*s.* 10*d.* a lb. when it contains less than 10 per cent. of moisture. Snuff containing no more than 13 per cent. of moisture, 4*s.* 10*d.* a lb.; 13 per cent. and upwards, 4*s.* 1*d.* a lb. Cigars pay 5*s.* 6*d.* a lb. Cavendish of foreign manufacture pays 4*s.* 10*d.* a lb.; that manufactured in bond, 4*s.* 4*d.* Other sorts, including cigarettes, pay 4*s.* 4*d.* a lb.

The approximate relative values in the London market are as follows:—Maryland, fine yellow, fine, and good coloured, 7–9½*d.* a lb.; colory, 5–7*d.*; light-brown and leafy, 5–7½*d.*; ordinary and brown, 4–4½*d.* Virginia: Fine Irish and Scotch spinners, 7–10*d.*; good and middling, ordinary light and dry, 6–10*d.*; fine black sweet scent, and middling do., 6½–7½*d.*; part blacks, 5–6*d.*; ordinary and heated, 3–5*d.*; mixed parcels, ordinary and good, middling and fine, 5½–6½*d.*; stripped leaf, 4*d.*–1*s.* Kentucky: fine long light leaf, 7–11*d.*; good to middling do., 5½–7½*d.*; fine and middling blacks, 6–8*d.*; ordinary and mixed, 2–5*d.*; stripped leaf, fine, light leafy, middling and ordinary, 4½–11*d.* Negrohead, 11*d.*–1*s.* 6*d.* Cavendish, 4½*d.*–1*s.* Amersfort and German, 2¾*d.*–1*s.* 6*d.* St. Domingo, 5–7½*d.* Havana, Cuba, and Yara, 1*s.* 2*d.*–6*s.* Turkish and Greek, 2½–9*d.* E. India, Japan, and China, 2–9*d.* Java, 5*d.*–2*s.* Colombia (New Granada), 5*d.*–2*s.* 6*d.* Manilla, 8*d.*–4*s.* Manilla cheroots, 4*s.*–7*s.* 6*d.* Havana cigars, 5–40*s.*

Tumbeki.—This word, under a multitude of forms, is the common name in several Eastern languages (Bengali, Hindustani, Telugu, Sunda, Javanese, Malayan, Persian, Guzerati, Deccan) for ordinary tobacco. But in Asia Minor, it is applied to a narcotic leaf which is spoken of as distinct from tobacco, and is separately classified in the Consular Returns. Botanical authorities are at variance as to the plant which affords it, some attributing it to a *Lobelia*, while others consider it a kind of tobacco. The latter appears to be the more correct supposition. The flower resembles the tobacco in being trumpet-shaped; the leaf is broader, larger, and rounder than that of the tobacco raised in Turkey, and is also wrinkled like the inner leaf of the cabbage. The plant is raised from seed in nurseries, and when it has 4 or 5 leaves, is planted out in April in the prepared field, and watered sparingly. It is "set" in a day or two, and is then hoed occasionally to free it from weeds. After inflorescence, and when the plant is sufficiently "cooked," it is cut down, or pulled up bodily, and re-set in the ground till the leaves are wilted. These leaves are dried, and, after exposure to the dew, are pressed heavily, when they undergo a kind of fermentation which develops the aroma. It is exceedingly narcotic: so much so, that it is usually steeped in water before use, and placed in the pipe (a *narghilé* or water-pipe) while still wet. The exports of this article (the produce of Persia) from the port of Trebizond are considerable:—In 1877, they were 13,342 bales (of 1¾ cwt.), value 106,736*l.*, to Turkey; in 1878, 11,571 bales, 92,568*l.*, to Turkey; in 1879, 9659 bales, 77,272*l.*, to Turkey, and 866 bales, 6928*l.*, to Greece. Aleppo, in 1878, sent 4 tons, value 320*l.*, to Turkey, and 11 tons, 880*l.*, to Egypt. The exports of the article, the produce of the interior of Persia, from Resht to Russia, were valued at 5000*l.* in 1877, and 3846*l.* in 1878.

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(See Alkalies [Organic]—Morphine; Drugs—Belladonna, Cocculus Indicus, Duboisia, Henbane, Lactucarium; Poppy, Hops).

NUTS (Fr., *Noix*; Ger., *Nüsse*).

The term "nuts" as applied commercially embraces a good many vegetable products which do not strictly belong to nuts botanically so-called. The chief nuts of commerce are the following.

Areca- or Betel-nut.—This is the fruit of the areca palm (*Areca Catechu*), which is cultivated in the Malay Archipelago, the warmer parts of the Indian Peninsula, Ceylon, Indo-China, the Philippines, and some of the Pacific Islands. It thrives in high regions, and at a distance from the sea; begins to bear fruit after 5 years, and is productive for 25 years. It flowers in April–May, and the nuts ripen in October; those most esteemed are gathered before they are quite ripe. A fruitful palm is said to produce 850 nuts annually, but the average may be taken at 300; the mean annual yield of a plantation is 10,000 lb. of nuts an acre. The fruit is a drupe, about the size of a hen's egg; it does not fall when ripe. There are many varieties of the palm. The nuts are dense and ponderous, and very difficult to break or cut. When freshly broken, they have a weak cheesy odour, and a slightly astringent flavour. In the green state, before they are ripe, the nuts are pounded up and chewed with the betel pepper or kava-kava, for the narcotic effects produced (see Drugs—Kava-kava; Narcotics—Ava); this is by far the largest and most important use of the nuts. Their quality depends upon the natural appearance when cut, indicating the amount of astringent matter contained in them. If the white or medullary portion which intersects the red astringent part be small, and has assumed a bluish tint, and if the astringent part be red, the nut is considered good; but if the medullary portion is in excess, the nut is more mature, possesses less astringency, and is inferior. The astringent properties of the nut are made use of in dyeing and tanning (see Tannin—Catechu). The exterior of the nut affords a fibrous material (see Fibrous Substances—*Areca Catechu*). The nut itself has medicinal uses (see Drugs—Areca-nut). The ashes of the nut are used in making tooth-powders, but possess no advantage over other vegetable charcoals. The toughness of the nuts enables them to be used for articles of turnery, but their smallness confines this use within narrow limits. The Eastern trade in these nuts is very large. The exports from Ceylon in 1878 were 101,777 cwt., value 92,869*l.*; in 1875, of the total export of 94,567 cwt., 86,446 cwt. went to India. In 1872–3, Madras exported 43,958 cwt. of the nuts, and 2 millions of the entire fruit, to Bombay. Penang exports some 3000 tons annually; and Sumatra, 4000–5000 tons. The Chinese port of Shanghai, in 1879, imported 1700 *piculs* (of 133⅓ lb.) from foreign countries, and 11,548½ *piculs* from Hong Kong and Chinese ports; the re-exports left only 1455 *piculs* for local consumption. Kiungchow exported 335½ *piculs*, value 450*l.*, in 1879.

Boma- or Booma-nut.—This nut much resembles an almond in shape and size, the fruit itself, with the fleshy covering, being about as large as a walnut. It is probably the fruit of a species of *Vitex*. It is a native of E. Central Africa, and is cultivated abundantly near the Victoria Falls; it is found also in the Shire Valley, but is said not to extend farther south than Lake Ngami. An oil is copiously afforded by it (see Oils—Boma).

Brazil- Castanha-, or Pará-nut.—The Brazil nuts of commerce, called *castanhas* in Brazil, are the produce of *Bertholletia excelsa*. The tree is a native of Guiana, Venezuela, and Brazil; it forms large forests on the banks of the Amazon and Rio Negro, and about Esmeraldas on the Orinoco. A large number of the nuts come from the rivers Tocantins, Xingú, Trombetas, and Curuá. The tree grows on low, rich *terra firme*, never on the flood-plains. The fruit is nearly round, and about 6 in. in diameter, with an extremely hard shell about ½ in. thick, containing 18–24 seeds, which constitute the commercial nuts. When the fruits ripen, they fall from the trees, and are gathered into heaps by troops of Indians, who visit the forests at this season for the purpose. They are then split open with an axe, and the seeds are taken out, sun-dried, and packed in baskets for transport to Pará in native canoes. They constitute a large article of export, some 90,000 bush., value over 35,000*l.*, leaving Pará every year. As they do not keep well in the Brazilian climate, they are shipped as soon as possible, largely to England and the United States, a few to France, Portugal, and Germany. They form a pleasant edible fruit, and yield an abundance of oil (see Oils—Castanha).

Bread-nut.—The seeds of *Omphalea diandra* and *O. triandra* are edible, and yield valuable oils (see Oils—Ouate, Bread-nut). They are cultivated, especially the former, in St. Domingo and Jamaica, under the names *noisettier* and "cob-nut."

Candle-nut.—The candle-nut, lumbang-nut, or country walnut (*Aleurites moluccana*, [*A. triloba*, *Jatropha moluccanum*, *Croton moluccanum*]), probably embracing several other varieties, is a native of the islands of the Pacific. It is found in N. Australia; abounds in the Moluccas, and most of the islands of the E. Archipelago, in the Malay Peninsula, Cochin China, and S. China; it occurs in California, Chili, and Venezuela; it is largely cultivated in Lower Bengal, and other parts of India; it is found in Bourbon and Mauritius; it has been introduced from Asia into the W. Indies, and has become naturalized in Jamaica. The fruit is the most valued product, and strews the ground beneath the trees at all seasons of the year. Each nut weighs about 160–170 gr., the kernel forming ⅓ of the total weight. The shell is covered with concretions of calcium carbonate. The juice is used for dyeing, and the calcined shells afford both a dye and a pigment. The kernels are eaten in most countries where the tree is common, usually after roasting or long keeping, or in combination with a condiment. Their flavour resembles that of walnuts or almonds. The nuts are commonly threaded on a reed or similar wick, and burnt for illuminating purposes. Analysis shows them to contain over 62 per cent. of oil, and more than 22 per cent. of nitrogenous substances; the proportion of phosphoric acid is 1·67 per cent.; and the ash contains 30 per cent. of potassium phosphate, 39 per cent. of magnesium phosphate, and 22 per cent. of calcium phosphate. These figures suffice to show its value as an ingredient of cattle-foods, could it be deprived of its purgative qualities. Tahiti exported 700*l.* worth of the nuts in 1875. Levuka (Fiji) sent nuts to London to the amount of 1562*l.* in 1876, and 3040*l.* in 1877. The oil has many uses (see Oils—Kukui).

Cashew-nut.—This is the fruit of *Anacardium occidentale*, a plant cultivated in the W. Indies, E. Indies, and other tropical countries. It grows on the W. African coast, from the Congo to Ambrizette, very abundantly. The plants yield a gum (see Resinous Substances—Cadjii). From the intermediate layer of the shell of the nut, is obtained a thick, black, oily, viscous juice, called *cardole* in the E. Indies. The kernels are eaten after having been roasted. They also yield an oil; and from them, an excellent wine is said to be prepared in Brazil. (See Oils—Cashew.)

Chestnut.—The edible fruit of *Castanea vesca* is well known. The tree is probably a native of S. Europe, from Spain to the Caucasus. In France, Italy, and Spain, it attains great size, and flourishes at 2500–2800 ft. in the Alps and Pyrenees. It is more abundant in Asia Minor, Armenia, and the Caucasus; and is also found in America as far north as lat. 44°. It ripens its fruit in the warmer parts of Scotland, but rarely, if at all, in Ireland.

It is very largely cultivated in Tuscany, where the method employed is as follows:—Plants are raised from the fruits, placed in earth which has been repeatedly worked. The plantations are generally situated near a stream, and the ground is shaded by hedges or trees. The space is divided into furrows, 6–7 ft. wide, in each of which, holes are dug about 3 in. deep, and at a distance of about 6 in. from each other. In these holes, the nuts are placed, with the germs downwards. The use of manure is not largely resorted to. After two years, the plants are transferred to another part of the plantation, where they remain four years, after which they are placed where they are to remain permanently. The season usually chosen for transplanting is after the falling of the leaves, though it is frequently done even as late as February–March. There are two methods of grafting the tree (which is done at the age of 5–6 years); one is the primitive method of inserting the bud in the end of a branch, with a slit in it, where it is retained by wax or other substances. The other, which has proved most successful, consists in cutting large rings of bark from the branches of the large or Spanish chestnut, and placing them on twigs of the ordinary kind; this is a very delicate operation, requiring great care, and is performed in the following manner:—The bark of the Spanish chestnut is cut into circles on the twigs, where marks of buds appear, care being taken to have one or more buds on each circle or cylinder, the bark is then slightly beaten to loosen it from its position, and gently twisted by hand, until a hollow cylinder of bark is obtained, which is then drawn up by the stem, that has been previously denuded of its bark in like manner. The cylinder of bark is then carried to the stem of the tree, which is grafted. This stem, having been previously denuded of its bark, and cut off down to the place where the ring is to be put on, is then covered with the ring, which unites with the growing bark, and sends out shoots of its own variety. In this manner, a tree is covered with these rings, and the natural branches being cut down, all the force of the tree is expended in throwing out the shoots of the large chestnut from the grafted branches. Great care is always taken to cut off all shoots of the common chestnut that may appear near the grafted part, as they will otherwise interfere with its full development. The operation of grafting by rings is practised in Tuscany from 10th April to 1st May, that being the time when the sap is running most freely, just before the leaves and buds come out. A method of preserving the grafting buds so that they may remain good even after a year, is to place them in tin tubes filled with honey, and hermetically sealed immediately on their removal from the tree. Another method of transporting the grafting buds is by putting them into hermetically sealed tubes filled with water; this method can only be used for transporting the buds for distances accomplished under forty days.

The nuts (to the number of 1–3) arrive at maturity in two months after flowering, that is to say in October, and then fall to the ground; they are also beaten from the trees by long poles, but this is only occasionally done, as it seriously injures future fruit-buds, and affects the yield of the tree for another year. The chestnut is pruned and trimmed every three years; this, while helping the tree to bear more abundantly, produces wood for fuel and other purposes, and small twigs and branches which are used for drying the nuts. After the nuts are gathered, they are deposited in huts, in the upper part of which deep trays are constructed, whereon the nuts are placed to the depth of 6 in.; in these huts, slow fires of green wood are kept up, until the nuts become hard and dry. They are then carried to a mill, where they are ground into flour, in the same manner as corn or wheat. From this flour, many preparations are made, such as "polenta," and various kinds of cakes, fritters, and even a heavy kind of bread.

There are many varieties of the chestnut, some of the best and largest not being adapted to the English climate; the most suitable are the Devonshire, the Prolific, and the Downton, the last remarkable for its short-spined husk. Chestnuts, after being well-dried in the sun, may be stored with dry sand in casks. In France, Spain, N. Italy, and Corsica, they form a most important article of food, and serve in a great measure as substitutes for potatoes and bread. The approximate export of these nuts from Spain in 1878 was 5,789,000 *kilo.* Italy, in 1874, had 1,224,711 acres under chestnuts, the produce of which was 11,351,282 cwt. The consumption in France is said to be 6 million bush. annually. Our imports have never reached 70,000 bush.; in 1870, they were 31,767 bush., about half from France, and the remainder from Spain and Portugal. (See Timber—Chestnut.)

The horse-chestnut (*Æsculus Hippocastanum*) affords a nut abounding in farinaceous matter, and though too bitter for human food, serves for feeding domestic animals. It yields a large proportion of starch (see Starch—Horse-chestnut), and a small quantity of oil (see Oils—Horse-chestnut).

The kidney-shaped kernel of the Tahiti chestnut (*Inocarpus edulis*) is roasted and eaten in the Pacific Islands, New Guinea, and the Moluccas, and forms a staple food in some districts. It is sweetish when boiled, or roasted in ashes, but is harder, and less pleasant and farinaceous, than the common chestnut.

The large seeds of the Moreton Bay chestnut (*Castanospermum australe*), a native of Queensland, are eaten by the Australian natives, but are hard, astringent, and little better than acorns.

Coco-nut.—The fruit of the coco-nut palm (*Cocos nucifera*) is too well known to need description. The tree flourishes with equal vigour on the coasts of the E. Indies, throughout the islands of the tropical Pacific, and in the W. Indies and tropical America. Its importance renders it an object of especially careful cultivation in many regions. On both the Malabar and Coromandel coasts of India, it grows in vast numbers; and Ceylon, which is peculiarly favourable to it, is estimated to maintain some 20 million trees. Many parts of the coast of Brazil teem with these palms; and in the W. Indies, great numbers are met with. The tree also occurs in considerable abundance on the coasts of tropical E. and W. Africa. But it seems most at home in the Pacific Islands. It is now attracting much attention from the colonists in Australia, where it is not yet established to any great extent.

Some 30 varieties of coco-nut are distinguished by the natives of the districts producing them, but many of these distinctions are obviously groundless. In preparing plantations, the nuts for sprouting are chosen fully ripe, with large eyes, and gathered from trees past middle age, and from clusters numbering few fruits. They should be gathered without injury, and neither be allowed to fall to the ground, nor to dry on the tree. They are carefully kept for not less than a month before planting, and are then set in an elevated plot, where water will not stagnate, and which is somewhat exposed to the influence of the sun. The planting may take place in January–April, also in August, provided the rains are not heavy. The seed-beds are dug 2 ft. deep, and the nuts are planted on their sides, 1 ft. apart at least, and leaving 2 in. unburied, some ashes, alone or mixed with salt, being put into the trenches. The beds are kept duly moist, but never made wet. In ordinary cases, the young shoots are transplanted in the 2nd–6th month after their first appearance; but in low-lying situations, it is preferable to wait till the 12th month. In low, damp spots, the transplanting may be done during the hot season; in salt-marshes, and on hill-sides, during the monsoon. It may be generally said that all sandy soils are suitable. Sunlight and sea-breezes are most beneficial.

Coco-nuts growing in mangrove soil on the side of creeks, and more or less saturated with salt, have their milk brackish, and the sap is saline also. These trees do not suffer from the attacks of the rhinoceros beetle, and are found to bear much sooner than those planted on a sandy soil. As an illustration of this, while trees planted at Penang 30 years ago, on sandy soil, have not yet borne fruit—although they are fine-looking trees—others in the same plantation, only 10 years old, but on low ground, where the sea tide comes up daily, washes their roots, and runs off again, are in full bearing, giving 50–100 nuts annually, and the kernel is as thick as that of nuts grown on sandy soil, and produces as much oil. The chief requisite with regard to a plantation in such a situation, is attention to the drainage. Longitudinal drains should be cut between the rows of trees, and cross ones at greater intervals. These drains must be kept clear, so as to allow the salt water to flow in and out freely. The tide is found to deposit amongst the trees a very fertilizing matter. If the drains are not attended to, and the water stagnates, the trees get dwarfed, and become thin towards the top, thereby preventing them from having a large crown.

The holes into which the shoots are transplanted should be 12 yd. apart on backwaters; but where a deep alluvial soil is found, 8–10 yd. are enough. In a level, loose soil, the hole should be a cube of 1½ yd.; on hill-sides, 2–2½ yd.; in low grounds, ½–¾ yd. deep, and 1 yd. sq. If the holes are not sufficiently wide and deep, the roots soon appear above the surface of the ground, their hold upon the earth is weak, sufficient nourishment is not obtained, and the monsoon storms will overturn the tree. In a cold clay, the holes are filled with sand, and the plant is deposited in it. In low marshes, banks or terraces should be thrown up and consolidated previous to planting. If, in any of these cases, plants 2–3 years old are used, the holes must be at least 2½ yd. every way. They should be dug 2–6 months before the planting, and be prepared first by having heaps of fuel and weeds burned in them, and subsequently by manuring. In low situations, new holes and quick planting may be preferred. No time should be lost in the removal from the nursery to the holes; indeed the day should not pass, in which case new roots and fronds may be looked for within the month; but where this proves impracticable, if the plants are kept cool and in shade, 4–8 days have been known to intervene, but to be followed by very great loss in the number of successful trees. Inside the holes, smaller ones are made, and filled with salt and ashes mixed with mould, in which the young plants are deposited, with the nuts just covered by the compost. Some shade must be afforded, and care taken that the plants are not shaken or removed from their first position; occasionally water should be sprinkled over them. The above compost must be used when there is but a small proportion of sand in the soil. Ashes will suffice on the sea-shore; and sand, in marshy and loamy soils. The broken roots of a plant under a year, and, according to many planters, all found on the nuts in the nursery, should have their ends cut, as new ones are supposed to be hastened by the process. Turmeric and arrowroot are often planted in the same pits with the coco-nut. After the plants are in, little *pandals*, or sheds, made of twigs and branches, should be erected to protect them, for the next six months, from too great sun-heat; this prevents the withering of the leaves, and any check to the growth of the roots. On dry soils, the plants are watered twice a day for the first month, once a day for the next five, or until the monsoon showers come on, and once every 2–3 days during the dry seasons of three following years, according to circumstances. On hill-sides, it is usual to water during the hot weather, even till the first buds appear; on sandy plains on the sea-coast, when the trees are in full bearing, 8–10 ft. of bamboo (with the divisions at the joints broken to form the pipe) is often driven down by the side of the tree, and cool water from weed-covered tanks is poured down to refresh the roots and lower soil. The soil round the young plant is often kept damp by a bed of leaves, particularly such as will not be eaten by white ants. If the soil is naturally poor, or of a hungry nature, salt, ashes, paddy-husks, goats'-dung, and dry manures may be applied for the first year; but in after seasons, oil-cake, fresh ashes, decayed fish, and other refuse, are preferable.

If the soil at the foot becomes too rich, a large grub with a reddish-brown head, soon finds its way to the roots and into the stem, and though the foot of the tree may enlarge, the stem does not develop itself, the new leaf-spike at the crown becomes yellow, fades, and is not replaced, and does not open out into the usual frond, and in 2–3 months the whole tree-top is affected and drops to the ground. It would appear that fear of this evil is the reason why ashes alone are recommended by so many cultivators. As soon as the new fronds have divided into the long side leaflets, or lost their connected form, which is at the end of the first year, the soil should be dug up, and ashes be applied about once a month. When the tree is two years old, and henceforward at the commencement of every monsoon in May–June, the whole of the soil, for 1–2 yd. around the stem, must be opened out, and ashes and dry manure be applied and left open to the air; in October, when the rains have ceased, this freshened earth should be replaced and levelled. As the tree gets older, and the depression at the foot is gradually filled up, it may not in after years be necessary to dig so deep as for the earlier growths. If the opening-out of the roots, and the manuring, be thus annually attended to, the tendency to form a sort of bulb on the surface, and throw roots above the soil, will be checked; the old worn-out rootlets are cut away, strong roots from other trees and all weeds are removed, and the process acts both as a "wintering" and a "pruning." Cattle are most destructive during the first two years, in eating off the ends of the fronds, and stripping the leaflets; if the plants suffer often in this way, the growth is entirely stopped; sometimes the new leaf-spike is pulled out, and the tree dies. Should the heart of the stem and top not be injured, the tree will still remain unsightly, and often entirely profitless.

From the time when the leaflets become fully developed and distinct from each other, till the period for the spathes (or covers to the flower) to make their appearance, the fronds should be shaken and weighed or pressed downwards each month, so as to keep them from each other and make them spread; and careful and frequent examination should be made, lest rats, beetles, or worms have made nests upon the head, or bored into the cabbage heart of the palm. Some planters sprinkle ashes and salt about the spike-shoots to keep insects away. The dried fronds, old spathes, fruit- and blossom-stalks, and ragged fibres, should be removed at stated periods of perhaps a month, or as often as the nuts may be gathered. The application of salt and ashes to the tree-tops is usual at least in March and October, to keep off the swarms of insects, particularly red ants, which live upon the juices of the tree, and render them fruitless.

The tree is all its life endangered by the attacks of enemies. One beetle bores into the tender shooting leaf, and lays its eggs there, to be hatched into grubs which will eat their way in all directions; another bores round holes into the stem itself and lives there; rats climb up and make their nests in the hollows of the branching fronds, and eat the cabbage itself, or feast upon the young kernels; the common flying-fox or rousette (*Pteropus*) gnaws round holes through husk and shell of the mature nut, and will attack the young nut, biting away large pieces from the tender part under the capsule; the flying squirrel (*Pteromys*) also makes its abode in near woods or forest trees, and at nightfall attacks the nuts; the common striped palm-squirrel is also sometimes found destroying the nuts and blossom; while red ants and parrots attack the blossoms only. The most effective methods of obviating these evils are to shoot the flying-foxes and squirrels by moonlight, and to poison the others by a mixture of arsenic with grated coco-nut pulp, or of pounded glass, oil, and black sugar, in coco-nut-shells, left in the tree-tops. Rats may be taken in trap-falls. The red ant's nest should be sought out and destroyed. A large wasp will attack the very small nut, taking it for the material of its nest. When the spathe is cut for drawing toddy, the frequent visits of the men will tend to keep some intruders away, but the smell of the toddy is said to invite others. Grass should be kept down by feeding off with goats and cattle; in marshy lands, cattle are apt to make deep tracks, and break down the margins of the terraces, hence goats or calves only are allowed. The undergrowth may be annually cut for repairing paddy-fields, and this is another source of profit. Planting jack, mango, tamarind, coffee, and other trees close to the palm, is thought to be detrimental, as is also allowing pepper and betel vines to climb the tree, and even the sowing of maize, gram, or any of the dry pulses under the shade. But areca-nut trees and all other palms may be planted, and the ground may be dug, and various kinds of yams and tuberous roots cultivated with advantage.

Under ordinary conditions, distinct leaflets begin to show themselves at the end of the 1st year, and are completed at the end of the second, on each frond, which will be 3 in. thick in the stem or leaf-stalk next the parent trunk. In the 3rd year, the bottom of the frond assumes a horse-shoe form where it clasps the main tree; in the 4th year, the trunk of the tree appears slightly above ground, and has not less than 12 fronds. About the 5th year, the trunk is fully manifested, and there should be about 20–24 fronds; when a luxuriant well-grown tree begins to bear fruit, there will be no less than 36 of these branches or fronds. Spathes or shoots, whence eventually the flowers emerge, begin to appear in the 6th year. The height of the stems at this important period, in some kinds usually, and in all when influenced by the soil, will be only 1–2 ft. above the ground; in other cases, it may be 16 ft. For the first few months, these flower-shoots are deceptive, and only dry up; but within the year, they begin to retain their blossoms and bear a few fruit, yielding abundantly in 3–4 years after their first appearance. In six months from blossoming, the kernels of the nuts begin to solidify: in a year, the fruit is fully ripe—even sooner if the season is very hot and dry. The produce of the tree in full health and properly tended is much dependent on soil and climate. The average may be put down at 120 nuts in the twelve months; in a low and sandy soil, it will amount to 200; in gravel and laterite, not 60. The most productive months in India are from January to June, that is for ripe nuts, the heat bringing them quickly to maturity. It is calculated that where the roots of the trees can reach water, and the soil is alluvial, the trees will bear 8–10 bunches of fruit; in other and higher lands, not more than 6. The trees bear until they are 70–80 years old.

When the trees begin to show spathes, they are often tapped for toddy, during the monsoon, and for that season only, this being supposed to render future fruit-branches more numerous, and to give the sap a tendency to flow. In some places, the trees are never allowed to bear fruit, but toddy is always extracted. If toddy is drawn for 6 months, it should not be repeated till at least 5 years have elapsed, otherwise the trees become exhausted, and produce no nuts. While some of the spathes are cut for toddy, the others will grow nuts, provided the number cut is not too great. Gathering some of the tender nuts from the earlier bunches greatly develops the succeeding branches, and strengthens the whole tree; but it is not recommended to cut the spathes out before they are matured or dry. Some 8–10 spathes dry and fall from each in a year, chiefly in the hot season; these should be removed when turning brown, leaving a small portion of the foot-stalk on the tree. The percentage composition of the nut is said to be:—Water, 39·7; oil, 29·3; amygdalin, 14; woody fibre, 9·5; sugar, 3·6; gum, 2·1; emulsin, 1·1; albumen, 0·5; mineral matter, 0·2. The exterior of the nut affords a valuable fibre (see Fibrous Substances—*Cocos nucifera*); the nut itself is very largely consumed as an edible fruit; and it is expressed to yield an oil (see Oils—Coco-nut), the remaining solid portion being largely used for feeding cattle. The trade in coco-nuts is very extensive.

Many years since, the Malabar coast was estimated to produce 300–400 million nuts per annum, worth 50,000*l.*; and the exports of copra were reckoned to have a nearly equal value. Travancore grew 5½ million trees 30 years ago, and the number has much increased since. In Cochin, the cultivation is very rapidly extending. The Madras presidency has over 200,000 acres under coco-nut palms. The value of the coco-nut plantations of Ceylon is computed at 15,000,000*l.*; their acreage in 1865 was 332,890; and the situation is chiefly in the north-western, northern, and southern provinces. More recently, the area is stated at 200,000 acres, and the production at 700–800 million nuts annually, worth 2,000,000*l.* The production varies exceedingly. Thus in 1866, over 128 million nuts were recorded, and others to the value of nearly 25,000*l.*; in 1868, only 30 million nuts and 28,000*l.* worth. The exports in 1870 were 5,478,677 nuts (and 623 bags), value 17,185*l.*; and 40,638 cwt. copra, value 31,678*l.* In Cochin China, more than 33,000 *hectares* (of 2½ acres) are occupied by coco- and areca-palms. The former is very abundant in the E. Archipelago, and the annual produce of the trees is estimated to be worth 2,500,000*l.* In 1874, Amboyna possessed over 500,000 trees; Banca, about 123,000; Minahassa, 600,000; Gorontalo, 250,000. Java and Madura number over 20 million trees. Plantations in the Straits Settlements are small and scattered, yet no district seems better suited to the cultivation of the nut. In the Straits of Malacca, the chief natural enemy of the tree is a species of elephant-beetle, which begins by nibbling the leaves into the shape of a fan; it then perforates the central pithy fibre, so that the leaf snaps off; and lastly it descends into the folds of the upper shoot, where it bores itself a nest, and, if not speedily extracted or killed, soon destroys the tree. A similar kind of beetle is known on the Coromandel coast, and is extracted by means of a long iron needle or probe, having a barb like that of a fish-hook. By using this, and by pouring salt or brine on the top of the tree, so as to descend amongst the folds of the upper shoots, the evil may be prevented or got rid of; the natives of Keddah say that this insect appears at intervals of 2, 3, or more years. The common kinds of the nut, under very favourable circumstances, begin to bear at 6 years of age; but little produce can be expected until the middle or end of the 7th year. The yearly produce of one tree with another may be averaged at 80 nuts. The quantity of oil which can be manufactured from 400,000 nuts will be, as nearly as possible, 834 *piculs* (of 133⅓ lb.). The coco-nut is foremost in importance among the vegetable productions of Borneo. The wars of the inhabitants have almost exterminated the plant from the W. coast, but it is abundant to the northward; and the Natuna Islands on the west, and Sulus on the east, are said to be covered with this palm. The rugged coral rock (limestone soil) and salt breezes of the Ke Islands seem very favourable to its growth, and it abounds up to the highest points, and produces fruit all the year round.

In New Caledonia, the coco-nut palm is abundant on the N.-E. coast, but rare on the opposite coast, and while it flourishes in a northern aspect, it declines towards the south. At Tahiti, there are about 200,000 of these trees, which produced over 12½ million nuts in 1874; about 600,000 nuts, and nearly 2,000,000 *kilo.* of copra, were exported. The Marquesas shipped 19,000 *kilo.* of copra in 1873. From the Tuamotus Archipelago, 3000 tons of copra were exported in 1873; the single island of Anaa is said to possess more than 7 million of the palms. Large plantations were made in 1866, and must now be in full fruiting. From the island of Samoa, in the S. Pacific, copra is the main article of export, but is the production almost solely of the German-owned plantations. In 1879, there were 12,921 acres of coco-nuts cultivated by whites in the Fiji Islands. Tahiti exported 174,400 coco-nuts, value 698*l.*, and 2113 tons copra, value 29,582*l.*, in 1878; and 150,000 nuts, value 600*l.*, and 875 tons copra, value 12,250*l.*, in 1879.

Coco-nuts are the chief production of the Seychelles, and the plantations are constantly increasing and extending from the beaches up to 1000–1500 ft. on the mountain-slopes. In 1879, 5278 coco-nut trees were recorded as growing in Curieuse Island, and 16,369 on Félicité Island. The best land is said to be already occupied by them. The method of extracting the oil is very primitive. Mauritius ships 40,000–50,000 nuts yearly.

In Jamaica, some thousands of the palm have been planted on sterile spots, such as the Palisadoes, running from Kingston to Port Royal. Several of the parishes possess over 100,000 fruiting trees each, and the number is constantly increasing. The tree abounds around nearly the whole seaboard of the island, but is singularly neglected. The annual export of 2 million nuts, worth about 5000*l.*, from the colony, gives no true index of the importance of the palm, nor the value it might have.

Trinidad possesses similar undeveloped resources, and the cultivation of the nut can be extended indefinitely on the eastern coast. The trees are in bearing all the year round, but some planters confine the plucking to three periods,—April, August, and December. The shipments in 1864 averaged only 250,000 nuts, but in 1876, they were 4½ million, and the total value was 18,000*l.*

The cultivation might be developed in Dominica with certain and immense advantage. The nut begins to bear in the 3rd year, the produce of the 4th year is very considerable, and that of the 6th is a "full crop." The cost of planting and cultivation are merely nominal, for in such situations as the valleys on the sea-coast, having extensive frontages of stony, barren, or swampy soil, the palm completely outstrips weeds and every other kind of vegetation. The number of coco-nut trees in the island is already considerable, and the nuts are of excellent size and quality, so that an extended production might easily be effected. It is receiving increased attention, being found to be one of the most easy and profitable cultivations. The exports from Dominica were 2,262,927 nuts in 1871, 2,660,905 in 1872, 2,380,871 in 1873, 3,974,400 in 1874, and over 4 million in 1875. Surinam exported 82,236 nuts in 1877, and 54,864 in 1878.

British Guiana had 10 estates under coco-nuts in 1879; the exports in 1880 were 1,197,908 nuts from Demerara, and 1050 from Berbice. British Honduras exported 381,680 coco-nuts in 1876, 604,399 in 1877, and 688,164 in 1878. The Bahamas have recently entered upon this industry, and there is promise of its attaining respectable proportions in a few years. The export of the nuts was 9518 in 1879. Some 80,000 trees have been planted in the colony since 1875.

Groves of coco-nut palms extend for about 280 miles along the coast of Brazil. From Para alone, about 7½ million of the nuts, worth 130,000*l.*, are annually shipped to the United States and Europe. The yearly produce of the island of Itamarca, on that coast, is about 400,000 nuts. Maceio exported 263*l.* worth of coco-nuts in 1876, and 138*l.* in 1879.

Coquilla-nut.—This is the produce of *Attalea funifera*, one of the palms affording piassaba fibre (see Fibrous Substances—*Attalea funifera*). It is of a dark-mahogany colour, oval, and 3–4 in. long, and is used for ornamental turning, and making the handles of doors, umbrellas, &c. The supplies have been curtailed by indiscriminate destruction of the trees, and the quality has much deteriorated.

Corozo- or Corosso-nut, or Vegetable Ivory.—The fruit of the *antá* (*Phytelephas macrocarpa*) forms the *marfil vejetal*, or "vegetable ivory" of commerce. The plant is confined to the northern part of S. America; and though yielding so useful a product, no serious attempt has been made to introduce it into any of our tropical colonies, despite the great promise of profit attending such a venture. In Jamaica, Trinidad, and Dominica, the plant would thrive along the banks of the rivers and streams, which run through many of the estates. The "nuts" are the seeds found in the interior of the fruit. They are collected by the natives, and shipped in large quantities to Europe, where they form the chief substitute for elephant-ivory (see Ivory), and are very extensively used for small articles of turnery, such as buttons. The exports of these nuts from Panama are constantly increasing, and at enhanced prices; the shipments to the United States in 1879 were of a value of 28,370*l.* The exports from Guayaquil have increased from 71,482 *quintals* in 1874, to 193,432 *quintals* in 1879; the province of Manabi also shipped 107,986 *quintals* in 1878. The consumption of the nuts despatched from Guayaquil is almost equally divided between England and Hamburg; but the cargoes sent from Manta and other Ecuadorian ports are chiefly for the latter market. Their value is 15–30*s.* a cwt.

The kernels of *Hyphæne crinita* and *Raphia Hookeri* have been imported as substitutes, but unsuccessfully. Those also of *Sagus amaricum* have been largely received from the Friendly Islands. It is probably this plant which is so abundant in the Solomon Islands of the S. Pacific, though the fruits are called "corosso-nuts." An ivory-nut palm belonging to a new species of *Phytelephas* is a native of Venezuela, and has been provisionally called *P. orinocensis.* The nut is like that of *P. macrocarpa;* but the plant, called *timiti* by the natives, has an erect trunk 8–10 ft. high. It may lead to ivory-nuts being exported from Bolivar and Trinidad.

Ginkgo-nut.—This is the seed of *Salisburia adiantifolia*, which is largely cultivated in China and Japan. The seeds are eaten, and yield an oil.

Ground- or Pea-nut.—This nut, called also earth-nut, monkey-nut, Manilla nut, and *minyak-katjang* or *katchang-tanak* (in Java, &c.), is the produce of *Arachis hypogœa.* The plant is extensively cultivated in all tropical and subtropical countries, especially India, the Malay Archipelago, China, Africa, and America. It might with great benefit be introduced into Australia. In W. Africa, it is cultivated in greatest abundance at a few miles inland, where the comparatively arid country is succeeded by better land and climate. It requires a good soil, and is therefore chiefly grown in the bottoms of valleys, or near rivers and marshes. The cultivation is exceedingly simple: the ground is cleared of weeds, &c., which are burnt, and after being hoed a few inches deep, the seeds are dropped in and covered over. Sowing takes place at the beginning of the rainy season, October–November; the first crop of nuts for eating green is ready about April, but they are not ripe till 9 months after sowing, or about July–August. The greater part of the crop of Angola and the Congo is grown in the Mbamba country, parallel with the coast, and 30–80 miles inland. The Indian-grown nuts are chiefly used locally as food, while some oil is obtained from them, mostly for adulterating other oils. Recent figures state the area occupied by it in India at 112,000 acres, and this is capable of very great extension. In Java, the nut is planted in high grounds, that are unfit for wet rice cultivation; after extraction of the oil, the refuse is used as manure. In Senegal and on the Gambia river, these nuts form a staple production, Cayor and Casamance furnishing the largest quantities. The American crop for 1880 was estimated as follows:—Virginia, 1,600,000 bush.; Tennessee, 1,100,000: N. Carolina, 120,000; total, 2,820,000 bush. Jamaica had 5 acres under ground-nuts in 1874–5, but only 2 in 1877–8. The important alimentary value of ground-nut meal may be judged from the following analysis:—Moisture, 9·6; fatty matter, 11·8; nitrogenous compounds, 31·9; sugar, starch, &c., 37·8; fibre, 4·3; ash, 4·6 per cent. It is thus far superior to both peas and lentils. The chief use of the nuts at present in Western commerce is for the oil which they afford (see Oils—Ground-nut); for the sake of this oil, they are largely imported to Marseilles, London, and Hamburg. The exports from the Gambia were 15,729 tons in 1858, and 13,000 tons in 1872; they fell to 10,000 tons in 1876, but reached the unprecedented figure of 29,396 tons in 1879. The exports from Sierra Leone in 1870 were 350 tons and 713,524 bush., all for France. Senegal exported 11,483,080 *kilo.* to France in 1874. The exports of ground-nut cake from Kiungchow were 17,600 *piculs* (of 133⅓ lb.) in 1877, 7942 in 1878, and 14,612⅓, value 5989*l.*, in 1879. The exports of the cake from Pakhoi were 250,000 *piculs* in 1879. Taiwan exported 10,619 *piculs* of the cake in foreign bottoms in 1879. The exports of the nuts from Amoy were 1666 *piculs* in 1877, and 695 in 1878. The exports from Grenada Island (W. Indies) were 451 barrels and 216 bags in 1878.

Hazel-nut.—The fruits of the wild *Corylus Avellana* are the common hazel-nuts; several species and varieties are distinguished, the principal being var. *barcelonensis*, affording the Spanish and Barcelona nuts, *C. Colurna*, yielding the Turkish kind, *C. tubulosa*, filberts; and *C. Avellana* var. *grandis*, the Kentish cob-nut. Some of the species are probably mere varieties produced by cultivation. The common wild nut is a native of all the cooler parts of Europe, N. Asia, and N. America. Of these nuts, our importations never exceed 300,000 bushels. The bulk comes from Spain. These, though afforded by one variety of tree only, are classified separately as—(1) Spanish: coming from Gijon, said to be sulphured, and will not keep for any time, arrive in bulk; and (2) Barcelona: kiln-dried, shipped from Tarragona in bags of 128 lb. The production of hazel-nuts is an important industry on the Turkish coast districts, extending from Athina to a little westward of Kerasund, and they constitute the chief riches of Kerasund, Tireboli, Ordos, Keureli, Yomurah, and Surmeneh. The best qualities are those of Kerasund and Tireboli. Since 1876, the nuts have been shipped from these places directly to Great Britain, and their yearly value is now upwards of 20,000*l.* The exports of nuts (including a few walnuts) from Trebizond in 1879, in sacks of 1½ cwt., were:—To Turkey, 11,862, value 17,793*l.*; France, 1924, 2886*l.*; Austria and Germany, 612, 918*l.*; Russia, 1150, 1725*l.*; Greece, 552, 828*l.*; Bulgaria and Roumania, 2004, 3006*l.*; total, 18,104, 27,156*l.* Filberts are of three kinds, white, red, and frizzled. The first is most commonly grown in this country. Hundreds of acres are planted with it in Kent, whence the London market is chiefly supplied. It is said that 30 cwt. an acre is sometimes raised on suitable land, affording a higher money return than probably any other crop grown in this country. Hazel-nuts afford a bland oil (see Oils—Hazel-nut).

Hickory-nut.—Several species of hickory-tree, all natives of N. America, afford edible nuts. The fruits of the Peccan or Illinois hickory (*Carya olivæformis*), a common tree on the Ohio and Mississippi, are light-brown in colour, and shaped like an olive; they are much superior in flavour to the nuts of any other species of the genus, and occasionally are found in English fruit-shops. The nuts of the shell-bark hickory (*C. alba*) are second in point of edible qualities. The nuts of nearly all these trees are valuable for their oleaginous properties (see Oils—Hickory-nut).

Kola-, or Guru-nut.—This name is applied to the seeds of *Cola* [*Sterculia*] *acuminata*, a tree indigenous to W. and central tropical Africa, and introduced by the negroes into Brazil and the W. Indies. These nuts are held in the highest estimation among the African races, for promoting digestion, and rendering stale water potable; and they form a most important article of commerce from the Angola to the Mediterranean. Chemical examination of the nuts has proved them to contain an alkaloid, similar to that of tea or coffee, and they are habitually used as substitutes for our ordinary dietetic beverages by foreigners residing in the localities producing them. They are said to promote digestion, support fatigue, and produce a generally bracing effect upon the system. When better known, they will doubtless be cultivated in our tropical colonies, especially as they flourish both on the sea-coast and inland.

Palm-nut.—The well-known palm-oil of commerce (see Oils—Palm) is the product of the outer fleshy coating of the seed of *Elæis guineensis*, a palm indigenous to W. tropical Africa, where it is found in great abundance, and whence it has been introduced into the W. Indies. Some oil is also yielded by the seed. The shell of the nut takes a fine polish, and is made into ornamental articles by the negroes. The geographical range of this palm in Africa extends from the coast of Guinea to the south of Fernando Po, and into the interior as far as Zhern, 400 miles from the sea, and the mouth of the Min, a tributary of the Niger. It flourishes also on the islands of Zanzibar and Pemba; occurs on the mountains of Usagona; and is plentiful around the lakes of Central Africa. Its limits are probably far from being yet defined. Strangely enough, beyond a successful attempt to introduce this most useful tree into Labuan, virtually nothing has been done to extend its range, and we remain absolutely dependent upon the W. African ports for our supplies of the oil. The following notes convey all that is known about the cultivation of the palm. The ground is first well-raked, and the ripe nuts selected for sowing are scattered broadcast over the prepared ground, and lightly covered with earth, or 6–10 nuts are dropped together into holes at various distances, and covered with earth. The planting is effected during the rainy season, as moisture is essential. When the young shoots are about 1 ft. high, they are carefully removed in the evening, and transplanted at distances of at least 15 ft. from each other; the best plan is to let them remain during 12 months, before performing the transplantation. The tree grows luxuriantly, and bears abundantly when it is 10–12 ft. high, if in a damp, semi-marshy soil, where water does not stagnate; but in dry, arid soil, it becomes stumpy, growing very slowly, and sometimes bearing fruit when only 4 ft. high. To ensure healthy trees, and a full crop of "fat nuts," the trees must be at least 20 ft. apart, and well supplied with water. The harvest of nuts fit for use is biennial, but the chief quantity of commercial oil is obtained from nuts gathered during the rainy season. The kernels now form a distinct article of trade, not less important than the oil itself: 27,873 tons were shipped from Lagos in 1878; 100,000 tons from Sierra Leone in 1870; 104 tons from the Gambia in 1877, and 87 tons and 91 bags in 1878. The meal left after expressing the oil from these kernels is one of the most valuable fat-producing foods for cattle, its analysis showing:—Moisture, 7·49; fatty matters, 26·57; albuminous compounds, 15 75; starch, mucilage, sugar, and digestible fibre, 37·89; woody fibre, 8·40; ash, 3·90 per cent.

Physic-nut.—This name is applied to the seeds of *Curcas purgans* [*Jatropha Curcas*], from the powerfully purging qualities of the oil expressed from them. The plant is indigenous to tropical America, and is very generally found in warm climates, being cultivated in Brazil, the E. and W. Indies, W. Africa, the Cape Verde Islands, the Philippines, &c. It is readily increased by cuttings, which rapidly take root, and is invaluable as a hedge-plant, the leaves being refused by all cattle. The Cape Verdes produced 16,672 tons of the seeds in 1869. The wider cultivation of the plant in our tropical colonies would be amply repaid by the oil (see Oils—Pulza).

Pistachio-nut.—Pistachio-nuts are the produce of *Pistachia vera*, a native of W. Asia, whence it has been introduced into S. Europe, and has there become very largely cultivated. The nuts are very generally eaten by the Turks, Greeks, and natives of S. Europe, either simply dried as a dessert-fruit, somewhat resembling almonds, or made into articles of confectionery. We import them in small quantities, both shelled and unshelled. The exports from Aleppo in 1878 were:—7 tons, value 420*l.*, to France; 32 tons, 1920*l.*, to Turkey; and 8 tons, 480*l.*, to Egypt. Bagdad in 1878 exported 9 cwt., value 52*l.*, to India and Europe.

Sapucaya-nut.—The seeds of *Lecythis Zabucajo* occasionally come in small quantities to this country. The tree is a native of Venezuela, Guiana, and Brazil, and grows indifferently on the *terra firme*, in the swamps, and on the edge of the flood-plains. The nuts are likely to supersede the closely-allied Brazil-nuts as a dessert-fruit, being far superior in flavour, and easier of digestion. They are more than 2 in. long and 1 in. wide. Our supplies are drawn from the Brazilian forests, and are shipped at Pará. The seeds of *L. ollaria*, whose fruits are known as "monkey-pots," and sometimes used in ornamental turnery, are less palatable.

Singhara-nut.—The singhara-nut of India is the produce of two species of water-chestnut, *Trapa bispinosa* and *T. quadrispinosa*, which flourish in the lakes of Cashmere, and in the ordinary water-tanks all over the upper provinces of Bengal. In Cashmere, the cultivation of these nuts is a most important industry, and it is estimated that they feed 30,000 people for 5 months in the year. Their more extended growth in all lakes, jheels, and inland waters in all parts of India is strongly urged as a step towards preventing future famines. The harvest or season when the nuts are mature lasts for 3 months, and the nuts may be stored for years in their horny outer skin, or the kernels may be taken out and sun-dried, and will then remain good for a long time. Another species, *T. natans*, is cultivated in S. Europe, and its nuts are often ground, and made into bread. Yet another species, *T. bicornis*, is the *ling* of the Chinese, whose seeds also form a considerable article of food.

Soap-nut.—The name "soap-nuts" or "soap-berries" is applied to the seeds of several species of *Sapindus*, from the fact of their being used in the tropics as a substitute for soap, their outer covering or shell containing a saponaceous principle in sufficient quantity to produce a lather with water. Among the species thus used are *S. Rarax* and *S. emarginatus* in the Old World, and *S. Saponaria* and *S. inæqualis* in the New. The round, hard, black seeds are used for small articles of turnery, and *S. emarginatus* affords a medicinal oil in India (see Oils). The seeds of *Acacia concinna* are used in India in the same manner as the soap-nuts proper. Soap-seeds figure largely in Chinese commerce. Hankow exported 1183 *piculs*, value 344*l.*, in 1879. Shanghai, in 1879, imported 1788 *piculs* from Chinese ports, of which, 744 were retained for local consumption.

Walnut.—The fruit of the common walnut (*Juglans regia*) is too well known to need description. The tree is found native from Greece and Asia Minor, over Lebanon and Persia, along the Hindu Kush to the Himálayas, and from the Caucasus almost throughout China, besides having been introduced generally throughout temperate Europe. In portions of the Alps and Apennines, it is very abundant, and is fairly plentiful in the forests of Lazistan, on the Black Sea, but is perhaps most common in Cashmere, whence come the walnuts imported into the plains of India. The green nuts form an esteemed pickle, and the ripe ones an equally favourite dessert-fruit, while in some places they are treated for the extraction of a valuable oil (see Oils—Walnut). Our supplies come mostly from the Continent. China produces immense quantities: the exports from Hankow in 1878 were 10,560 *piculs* (of 133⅓ lb.), and in 1879, 9766 *piculs*, value 12,829*l.*; the exports from Chefoo fell from 5001 *piculs* in 1870 to 1693 in 1879.

Preparations of the walnut are included among medicinal agents on the Continent, notably an extract of the dry leaves. From experiments made with preparations from leaves collected in June, and in October, and leaves 12 months old, it would appear that the full-grown leaves may be collected at any period during fine weather, even as late as October, when they can be removed without injuring the tree. The extract should be prepared with such leaves recently dried. The leaves falling in autumn should not be used, though there is reason to suspect that they are often employed in preparing the commercial extract. When the leaves are of good quality, they have a fine green colour on the upper surface, and a darker green beneath, with brown petioles. They have a parchment-like texture, an aromatic odour, and a freely bitter and astringent flavour. Altered leaves lose most of their odour and flavour, and assume a brownish tint. Fallen autumn leaves sometimes show yellow spots.

Imports.—Our imports of nuts and kernels, mostly used for expressing oils therefrom, in 1879, were as follows:—From the W. coast Africa (foreign), 11,629 tons, value 158,571*l.*; Gold Coast, 9666 tons, 131,094*l.*; Australia, 4845 tons, 95,319*l.*; Pacific Islands, except Fiji, 3041 tons, 61,413*l.*; British W. Africa, 2748 tons, 33,994*l.*; other countries, 2437 tons, 41,379*l.*; total, 34,366 tons, 521,770*l.*

Bibliography.—P. L. Simmonds, 'Nuts, their Produce and Uses' (Jour. Soc. Arts., Vol. xx., No. 1014, London: 1872); P. L. Simmonds, 'Tropical Agriculture' (London: 1877).

OILS AND FATTY SUBSTANCES (Fr., *Huiles et Corps Gras*; Ger., *Oele und Fettwaaren*).

The dual heading "oils and fatty substances" is rendered necessary by the fact that, in everyday language, the specific terms "oil" and "fat" are very widely, and often erroneously, applied. The name "oil" is made to embrace three distinct classes of bodies:—(*a*) "fixed" or "fatty" oils, (*b*) "volatile" and "essential" oils, and (*c*) "petroleum" and other "mineral" oils.

The first class comprises a number of organic bodies, composed of carbon, hydrogen, and a little oxygen, viscid liquids, communicating a permanent stain to paper, insoluble in water, and, as they occur in nature, mostly mixtures of different simple fats, which, by saponification, are resolved into fatty acids and glycerine. For further information upon the subject of saponification, the reader is referred to the articles on Candles and Soap; the identification of the fatty acids is discussed under the section of the present article entitled Detection and Analysis. The term "fat" is applied to these oils when they are in a solid state; thus the same product may be an "oil" in one climate, and a "fat" in another.

The second class, volatile and essential oils, consist either wholly of carbon and hydrogen, or of these elements supplemented by less proportions of oxygen, nitrogen, and sulphur. They have a thin, oily consistence, volatilize completely at high temperatures, possess powerful and peculiar odour and flavour, are very inflammable, and sparingly soluble in water. Many of them occur ready formed in organic bodies, chiefly of the vegetable kingdom, and are then true essential oils; others, which are volatile but not essential, are produced by dry distillation, fermentation, and other changes.

The third class, mineral oils, belong strictly to the preceding, being true volatile oils; but their immediate sources, preparation, and application, differ so widely, and they form, moreover, such an important branch, that it will be best to consider them separately. Neither essential nor mineral oils can be spoken of as "fatty substances."

The arrangement adopted in this article is as follows:—Oils and Fats derived from Animals, Fish, and Insects, whether fixed or volatile (p. 1361); Fixed Oils and Fats derived from Plants (p. 1377); Volatile and Essential Oils derived from Plants (p. 1415); Mineral Oils (p. 1433). These main sections will be followed by various General Considerations bearing upon the whole subject, and embracing Improved Modes of Extraction (p. 1447); Refining, Clarifying, and Bleaching (p. 1459); Detection and Analysis (p. 1462); Illuminating Values (p. 1477); Heating Values (p. 1478); Lubricating Values (p. 1479); Boiling, Oxidizing, and Vulcanizing (p. 1482); Imports (p. 1482); Prices (p. 1483); Bibliography (p. 1483).

ANIMAL, FISH, AND INSECT OILS AND FATS.

Blackfish-oil.—The term "blackfish" is very promiscuously applied by whalers, and includes the common black whale of the Australian seas (*Balæna australis*), *Physeter microps*, and *P. Tursio*, besides the pilot whale (*Globiocephalus Svineval*), the American *G. intermedias*, and the killer (*G. macrorhyncus*) of the South Sea whalers. The two species of chief importance as oil-yielders are *G. intermedias* and *G. macrorhyncus*. The former is pursued by the Tasmanian whalers, and affords an average of 30–35 gal. of dark, unpleasantly odorous oil. This fishery, in 1869, produced 13 tuns; in 1873, 12½ tuns; and the exports in 1875 were 25 tuns, value 965*l*. The American cetaceans appear about the shores of Cape Cod and Barnstaple Bay from early summer till early winter. They are surrounded by boats, and frightened till they beach themselves in endeavouring to escape. They are then lanced, and when the tide leaves them, their blubber is cut out, and "rendered." The product is about 30 gal. of oil. In addition, a portion of the head, reaching from the spout-hole to the end of the nose, and from the top of the head to the upper jaw, and forming a piece weighing about 25 lb., affords some 6 qt. of a very limpid oil, which is commonly termed "melon-oil." This oil is said to have an unusually low congealing-point, and to have no corrosive effect on metallic surfaces; it is specially prepared by a few firms in the United States as a superior lubricator for delicate mechanisms. (See also Spermaceti, p. 1371; Whale-oil, p. 1374).

Bone-fat (Fr., *Suif d'os*, *Graisse d'os*, *Petit suif*; Ger., *Knochenfett*).—A fat of varying quality is obtained from slaughter-house and kitchen bones, by boiling them in water, previous to their utilization for articles of turnery, manurial purposes, &c. The conduct of the operation and the nature of the products are described in the article on Bones (p. 521). Some improved methods of separating fat from bones will be found under another section of this article (see p. 1448).

Bone-oil, Dippel's Oil, Animal Oil.—In the dry distillation of animal gelatinous substances, the oil known by these various names is produced, it being a result of the decomposition of gelatinous tissue. That first introduced into pharmacy was obtained from stags'-horn, but all now found in commerce is recovered as a product of distillation during the calcining of bones for the preparation of animal charcoal or bone-black. The operation is described and illustrated on p. 1450. The crude oil is dark-brown to black; its sp. gr. is 0·97; it consists chiefly of a mixture of volatile organic bases, with lesser proportions of acids and neutral hydrocarbons.

Butter (Fr., *Beurre*; Ger., *Butter*).—The fatty portion of the milk of all mammalian animals is called "butter," but the term in a commercial sense is restricted to that from the cow. The methods adopted for making butter vary widely throughout the world, but the object of the operation is always the same, viz. to rupture the thin membranous sacs in which the butter is disseminated through the milk, and to enable their contents to coalesce. Butter is produced in most countries which possess pastures, but in some much more extensively than in others. The quantity made annually in the United Kingdom is estimated at 1½–2 million cwt. Much of this is Irish, Munster being the great butter-producing province. The chief ports for its shipment are Cork, Waterford, Limerick, and Belfast. Cork monopolises the foreign export trade, and the butter shipped there is usually more heavily salted, with a view to its longer preservation. The supplies from the other three ports are less strongly cured, and better adapted for immediate consumption. About ⅓ of the total exports go to foreign markets, principally to Brazil, smaller quantities to the Mediterranean, W. Indies, and Australia. Irish butters are divided into six qualities, and are esteemed inferior to good Continental butters. France is noted for its butter, the foremost quality being from Isigny, and including not only that made in the district, but also the best produce from Normandy and Calvados. The Gournay butter, made in the departments of Eure and Seine-Inférieure, ranks second. French salted butter comes from Brittany, especially Morlaix, Rennes, Nantes, and Vannes. Dutch butter is of three kinds—(1) "grass" butter, made from cream when the cows are at grass; (2) "hay" butter, made from cream when the cows are being stall-fed; (3) "whey" butter, made from the whey of new-milk cheese. A peculiarity in the Dutch way of making cream butters is the cooling of the new milk by cold-water troughs for a couple of hours, the milk being stirred meanwhile. This hastens and perfects the separation of the cream. American butters are now said to be largely adulterated with powdered soapstone or steatite (a natural silicate of magnesia), which increases the weight without affecting the bulk. For shipment to warm climates, butter should be packed in 1-lb. or 2-lb. glass bottles, with mouths about 2 in. across, and fitted with glass stoppers with a cement that will keep air-tight. A spoonful of the very best salt should be added at the top before stoppering. French butter is thus sent to the E. Indies.

The commerce in butter is extensive. The exports of butter from European Russia have risen from 112,925 *poods* (of 36 lb.) in 1873, to 174,110 *poods* in 1878; in 1871, they amounted to 237,401 *poods*. The exports from Sweden have grown from 69,815 *centners* (of 93¾ lb.) in 1873, to 89,908 *centners* in 1878. The Danish exports have increased from 35,547 *tönder* (of 3·82 bush.) in 1868–9, to 102,140 *tönder* in 1878; they were 142,703 *tönder* in 1876. The exports from the German Empire were 258,000 *centners* (of 110¼ lb.) in 1872, and 244,000 *centners* in 1879. The exports from Holland have risen from 15,246,000 *kilo.* in 1872, to 36,451,000 *kilo.* in 1879. The exports from Belgium have grown from 3,784,000 *kilo.* in 1871, to 5,231,000 *kilo.* in 1879. The exports of butter and cheese together from France rose from 21,309,000 *kilo.* in 1870, to 43,081,000 *kilo.* in 1876; but fell to 31,598,000 *kilo.* in 1879. The exports from the United States have increased from 2,019,000 lb. in 1870, to 38,248,000 lb. in 1879; Philadelphia shipped 605,529 lb. in 1879. The exports from Canada fell from 170,254 cwt. in 1872, to 82,752 cwt. in 1875, then rose to 138,210 cwt. in 1877, and were 129,787 cwt., value 445,510*l.*, in 1879. The value of the butter exports from Natal fell from 8403*l.* in 1869, to 689*l.* in 1876, and was 1724*l.* in 1878. These statistics include all substances declared as butter to the Customs authorities. Large quantities of artificial compounds help to swell the figures, notably those of Holland and the United States.

The quality of butter depends upon the season, and upon the breed, health, and diet of the animal. It is a complex compound of glycerides, of non-volatile acids (fats), and of volatile acids. It should contain at least 85 per cent. of pure fat, the remaining constituents being 3–5 per cent. of caseine or curd, imperfectly washed out; 5–12 per cent. of water, according to whether it is fresh or salt butter; and 4 per cent. of salt in fresh, and 8 in salt butter. Its true melting-point, as determined by Hassall, ranges from 32°·8 (91° F.) to 34°·9 (95° F.), the mean being about 33°·5 (92°·3 F.). It dissolves in 28 parts boiling alcohol of 0·82 sp. gr. Dr. Hager has fixed the sp. gr. of butter at 15°–16° (58°–60° F.) at 0·938–0·940 when clarified by settling, and at 0·936–0·937 when several months old. It is most extensively adulterated (see Butterine). The most reliable tests for the detection of admixtures of foreign fatty substances in butter will be found in the section devoted to detection and analysis (see p. 1465).

Butterine, Bosch, Oleomargarine, or Artificial Butter (Fr. *Margarine-Mouries*).—Within the last decade, a new and important manufacture has sprung up in consequence of the dearness and scarcity of butter. It was initiated in France, and the product was called *Margarine-Mouries*, from the name of its inventor; in this country, it is variously styled "butterine," "bosch," "oleomargarine," and "artificial butter." It originated from a surmise of the eminent French chemist Mège-Mouries, that the formation of butter contained in milk was due to the absorption of fat contained in the animal tissues. This led to the experimental splitting-up of animal fats, with the result that a process was devised by which the oleine and margarine contained in the fat could be almost completely separated on a commercial scale from the stearine. This process consists in heating finely-minced beef-suet with water, carbonate of potash, and finely-chopped fresh sheep's-stomachs, at a temperature of 45° (113° F.), when the combined influence of the pepsine of the sheep's-stomachs, and the heat, causes the separation of the fat from the cellular tissue. The fatty matters are removed, cooled, and submitted to powerful hydraulic pressure in the cold, which effects their determination into a solid and a liquid portion, the former being stearine, a commercially valuable article, and the latter the oleine and margarine, or oleomargarine, required for making the artificial butter. This is the process patented by Mège-Mouries, and under which a large proportion of the butterine is made.

A method that is very extensively employed in the United States consists in thoroughly washing the picked beef-suet in water, and placing it in a steam-jacketed pan; the contents are never allowed to experience a temperature exceeding 49° (120° F.). The pure fat that runs off is "seeded" (i.e. allowed to cool very slowly, which facilitates the mechanical separation of the stearine) and pressed. The resulting stearine is sold for candle-making purposes, while the liquid portion (oleomargarine) is used in the manufacture of butterine.

Another arrangement is adopted by W. Cook and S. Hall of the E. London Soap-works, Bow. The freshest beef-suet is first thoroughly disintegrated and reduced almost to a pulp. A wooden chamber is provided, of sufficient height to accommodate a workman, and with a passage up the centre. At the two sides, are inclined racks; upon these, shallow iron trays are slid in from the outside, and rest with a slight slope towards the central passage. Along the lower free edge of each row, is an open iron gutter, leading to a receiver outside. The comminuted fat is laid in thin layers upon the trays, and the temperature of the chamber is raised by steam-pipes to such a degree as will just suffice (and no more) to liquefy the fat, which then escapes by the gutters to the receiver, leaving behind such shreds and portions of tissue as are not liquefied by the heat. The temperature should never exceed 54°–57° (130°–135° F.), and a much lower degree will be equally effective by prolonged time. The product (oleomargarine) is remarkably fine and fit for food.

The residual matters, still containing 6–7 per cent. of tallow, are mixed with kitchen-stuff, and rendered by the ordinary process described in another section (see pp. 1447–8).

The oleomargarine obtained by either of these processes is too limpid for use alone. It is mixed, either in the locality of production, or after exportation (in barrels or tierces, under the name "oleomargarine," "butter-fat," or simply "oil,") to butter-producing districts, with proportions of milk, water, and colouring matter. The usual proportions are 10 lb. oleomargarine, 4 pints milk, and 3 pints water, with a little annatto and salt. It is important to remark that (in America at least) the milk is invariably used in a slightly sour condition. The whole is churned up with the greatest care as to the temperature at which the operation is conducted, and is then suddenly run out in thin layers upon sheets of ice to cool it rapidly. It is finally made up in "pats" and packed, in every respect the same as genuine butter. The characteristics which distinguish it from true butter are described at p. 1465. A compound termed "creamy butterine," recently put upon the market in large quantities, has the taste, appearance, and odour of butter, and yields 92 per cent. of insoluble fatty acids. New York manufacturers state that, when the retail price of genuine butter falls below 23 cents (say 11½*d.*) a lb., it does not pay to make butterine. The average wholesale prices of the oleomargarine oil and the manufactured butterine ruling in New York since 1876 have been 13 cents and 15 cents a lb. respectively. As to the nutritive value of butterine, French official reports pronounce it superior to butter. On the score of its liability to contain organic germs likely to produce dangerous or fatal results in persons eating it, there is a marked want of agreement among scientific men. Much probably depends upon the care used in the selection of the fat and in the conduct of the manufacturing process; where inferior fats are employed, as it is to be feared is sometimes the case, it seems impossible to avoid a dread of evil consequences. Complaints are made that quantities of Chicago pig-lard are being introduced by some makers.

The manufacture of butterine has assumed very large proportions in the United States; it is chiefly carried on in New York, but factories also exist in Philadelphia, Pittsburg, Chicago, Cincinnati, and other cities. It is estimated that at least 6 million lb. of oleomargarine are exported annually from New York. The shipments take place almost entirely to the Continent, Havre, Hamburg, Bremen, and Rotterdam being the most important destinations. In the warm months, the oil is the main export, although the prepared butterine is also shipped in refrigerators by steamer. During the winter months, both oil and butterine are exported, the latter chiefly to the United Kingdom, but its proportion is comparatively small in relation to the oil sent to the Continent. After the oil has been converted into butterine in Germany and Holland, it is re-shipped to England and France, mainly the former.

Cod-liver-oil (Fr., *Huile de Foie de Morue*; Ger., *Leberthran*).—A valuable oil is afforded by the liver of several fish of the genus *Gadus*, notably that of the common cod, *G. Morrhua*. The chief seats of the cod-fishery are the coasts and banks of Newfoundland, Nova Scotia, the Gulf of St. Lawrence; the W. coast of Norway, from Stavanger nearly up to Hammerfest, and including the Loffoden Islands; the coasts of Denmark and Germany, commencing at Römö on the W., passing through the Skager Rack and Cattegat, and extending E. to Dantzic; the coasts of Shetland, Færoe, and Iceland, and the Dogger Bank in the North Sea.

The methods in vogue for extracting the oil from the cods' liver are not everywhere the same. The common plans at the less advanced fisheries, as in Iceland and the Finland ports, are as follows. The clear oil is obtained by throwing the livers, directly they are brought ashore by the fishermen, into large wooden reservoirs or barrels, where, after having been subjected to uniform stirring, they remain till decomposition has taken place. The effect of this is to cause the rupture of the cells containing the oil, which latter then escapes, and collects on the surface. It is drawn or ladled off as it rises, and conveyed into larger vessels for clarification by settlement of the impurities, afterwards being filled into casks for sale. The oil will be observed to darken considerably in colour as the decomposition progresses, and is somewhat deteriorated thereby. The burnt, brown, or tanners' oil is obtained from the solid remains left from the preceding process, which are placed in iron kettles, and boiled till all the water contained in the liver is evaporated; this also liberates the oil, which is strained, clarified, and barrelled like the first quality.

These crude processes have been considerably modified in Newfoundland and Norway. The livers reserved for the preparation of medicinal oil are taken as fresh as possible, always within 12 hours of the capture of the fish. They are very carefully examined, and those which are poor or injured, or have pieces of gall adhering, are rejected. The selected livers are then thoroughly washed and dried. They are immediately put into open barrels, where the oil slowly exudes, and is ladled from the surface. When quite cold, it is filtered several times through blotting-paper, and put up in tin cans or oak barrels. It is of a straw-yellow colour, almost devoid of taste and smell, and is known as "natural medicinal." The livers are then placed in tinned sheet-iron pots, suspended in water contained in a larger pot—a kind of water-bath; the heating of the water causes the oil to exude from the livers. Sometimes the heating medium is steam, and in other cases, the steam is directly applied to the livers themselves. The temperature at which the operation is conducted appears to differ most materially. At some works, it is not allowed to exceed 44½° (112° F.); while at others, it is raised to 82° (180° F.). The occurrence requiring to be specially guarded against is the breaking-up of the livers before the oil has been removed from the vessel, otherwise infinitesimal portions of animal matter mingle with the oil and subsequently putrefy in it, thus lowering its value. The exuded oil is skimmed off, and "reduced" or "boiled away" till all the water has evaporated from it. It is then filtered four times through filter-paper or very fine muslin, to free it from all remaining solid impurities. The yield of oil depends upon the condition of the fish, which varies exceedingly with the season. Early in the season, they are rich in liver, so that 250-300 fish may give a barrel of liver; as the season advances, they become poorer, till 600–700 are required to give the same quantity of liver.

The classification of the product naturally depends upon the systems which are in vogue for its preparation. The most usual subdivision is threefold:—(1) The palest and purest, termed "steam-boiled medicinal" or "ordinary bright," used only in medicine; (2) a somewhat redder after-yield, called "light-brown," inferior for medicinal purposes, but largely used for such; (3) the "dark-brown," or "tanners'," obtained by roughly boiling down the livers remaining from the foregoing processes. The last is settled in large receiving-tanks, racked off, and barrelled. It is largely used by tanners and curriers. The best is said to be from Newfoundland; that from Labrador fetches 2–4 cents a gal. less in the market. The refuse solid materials remaining after all the oil has been extracted are added to other offal for making fish guano (see Manures). The chemical and physical characteristics of the three qualities of the officinal oil as classified by de Jongh are as follows:—(1) Palest and clearest: colour, golden-yellow; sp. gr., 0·923 at 17½° (63½° F.); soluble in 40 parts cold and 22–30 parts boiling absolute alcohol; deposits a white fat at −13° (9° F.); (2) pale-brown: colour, that of Malaga wine: sp. gr., 0·924; soluble in 31–36 parts cold and 13 parts boiling absolute alcohol; (3) brown: colour, dark-brown, greenish by transmitted light; sp. gr., 0·929 at 17½° (63½° F.); soluble in 17–20 parts cold or hot absolute alcohol; deposits no solid fat at −13° (9° F). The oil consists chiefly of oleine and margarine, and contains small proportions of iodine, bromine, and free phosphorus, besides peculiar constituents. It is very largely prescribed in medicine, its efficacy being probably due to the bromine, iodine, and phosphorus present, though opinions are not uniform on this point. Many other oils are substituted for true cod-liver-oil. That obtained from the ling (*Gadus* [*Lota*] *Molva*) is recognized by the London pharmacopœia. The liver-oils of the dorse (*G. cellarius*), and the coal-fish (*G. carbonarius*) were formerly supplied to Great Britain from Bergen, and are still chiefly used in Germany and Scandinavia. The burbot (*Lota vulgaris*) also contributes to the liver-oil prepared in the Shetlands, &c. Besides these, the oils extracted from the livers of the haddock, hake, cat-fish, conger-eel (p. 1375), ray (p. 1376), shark (p. 1370), and probably many others, are surreptitiously mingled with the cod-liver-oil of commerce.

The trade in cod-liver-oil and its substitutes has attained considerable dimensions, and is of great importance to the population of certain districts. The annual production of Newfoundland is said to amount to 1¼ million gal., value 200,000*l.*; the exports of unrefined cod-liver-oil were 2275 tuns (of 210 gal.), value 113,757*l.*, in 1864, and 2946 tuns, value 49,618*l.*, in 1878; the highest figure reached during that time was 4140 tuns, 138,000*l.*, in 1869; the lowest was 2268 tuns, 75,600*l.*, in 1876; the exports of refined cod-liver-oil were 171 tuns, 26,380*l.*, in 1864, and 63 tuns, 2520*l.*, in 1878; the highest figure reached during that time was was 419 tuns, 27,944*l.*, in 1865; the lowest was in 1878. The French cod-fisheries on the Newfoundland coast were said to have yielded an average of 560,000 *kilo.* of oil in the five years ending 1871. The Norwegian fisheries exported 130,600 barrels, value 386,600*l.*, in 1877; the estimated exports in 1878 were 66,000 barrels (of 100 *kilo.*), of which, 4000 were white steam-prepared oil, 12,000 yellow medicinal, 12,000 common oil for industrial purposes, 8000 brownish-yellow, and 30,000 brown tanning, considerable quantities of which are still used medicinally on the Continent. The Loffoden fisheries, in 1879, afforded about 2750 barrels of medicinal oil, and 33,500 barrels of blubber; the Finmarken fisheries, in the same year, produced 3080 barrels of medicinal oil, and 25,000 barrels of coarser oil; the Söndmöre fisheries also gave some 2700 barrels of medicinal oil. The total exports of cod-liver-oil from Sweden and Norway in 1879 were 143,165 *hectol.* (of 22 gal.).

To the foregoing account, R. G. Clements, of Hackney, has been good enough to add remarks substantially as follows. For many years the Newfoundland oil was considered the only sort safe for medicinal use. Norway attempted the extraction, but the imperfect method of its preparation caused it to be neglected in the London market. Of late years, however, great improvements have been made, and now that the Norwegian oil comes in tin-lined casks instead of simply wooden ones, it has quite superseded the Newfoundland brand. An exceedingly fine oil may be prepared on a domestic scale by selecting the quite fresh livers, washing and drying them, puncturing them all over with a pen-knife, and placing them on a dish before a fire. In Norway, three industrial methods are in use:—(1) Exposure to the sun, then boiling in water, and skimming off the oil; (2) packing into vats provided with three taps, when, after remaining long enough, the oil floats, and is let off by the taps, the uppermost giving the best; (3) cutting into slices, and exposing to a temperature of 82° (180° F.). All livers which have yielded cold-drawn oil are afterwards exposed to moderate heat for the extraction of straw-coloured oil, and then to stronger heat for brown oil. The property demanding chief attention in oil for medicinal purposes is the presence of free iodine (not added), and all wholesale dealers determine its proportion (by the usual sulphuric acid test) before purchasing the oil.

Crocodile-oil.—The oil of the Indian crocodile contains a larger proportion of solidifiable fat than either neats'-foot or any fish oil. It solidifies at the melting-point of ice, while the others only thicken. In comparison with the softening qualities of other animal oils on leather, it has been found that leather treated with crocodile-oil remained much stiffer than when other animal oils were used. It has been inquired after for leather-dressing in this country, but is not yet a commercial article here. It is prepared by the Sanif tribe, in the Punjab, who eat crocodile-flesh, and it is said to be abundantly procurable at Agra.

The fat of the alligator (*Alligator lucius*) is largely utilized. The tail of an alligator of 12 ft. in length, on boiling, furnishes 50–70 pints of excellent oil, which, in Brazil, is used for lighting, and in medicine. The alligators of Central America and the United States might be similarly turned to account.

Dugong-oil.—Of the "dugong," "sea-hog," *yungan*, or *mooda hoora*, there are two species, *Halicore australis*, and *H. indicus*, each yielding an oil of great value in medicine and cooking. The latter species is distributed throughout the Indian Ocean, abundantly in the Gulf of Manaar, on the W. coast of Ceylon, between Adam's Bridge and Kalpentyn; also in the Straits Settlements, and the Eastern Archipelago. The former species is found on the Australian coasts, from Brisbane northwards along the Great Barrier Reef; in the Gulf of Carpentaria; in Shark's Bay, W. Australia; and along the N.-W. coast. The pursuit of the animal by Europeans on an industrial scale is almost confined to the Queensland coast, chiefly in Moreton Bay, Wide Bay, Hervey's Bay, Cleveland Bay, and the mouth of the Pioneer River. Only one vessel is said to be engaged in this fishery at Shark's Bay, W. Australia; in Ceylon and the Straits, this industry seems to be totally neglected, except by the Malays, who hunt the animal for food.

The animals frequent shallow waters, where the depth does not exceed 2–4 fathoms, and feed on the sea-grasses found in such localities. Their habits are essentially gregarious, and they are sometimes met with in immense herds. The method of capture adopted by the Australian blacks is to surround the creatures on their feeding-grounds, and drive them landwards, where they kill them by spears. Netting is sometimes successful on a retreating tide; and harpooning is also practised from boats, which requires great skill and caution. The wariness of the animals places an obstacle in the way of a development of the industry, as they suddenly desert a feeding-ground and appear elsewhere, where no provision has been made for boiling them down. The assistance of a tender carrying the necessary apparatus will probably have to be brought into requisition.

The size of the Indian animal varies from 6 to 10 ft.; the Australian sometimes reaches a length of 15 ft. The weight of an average specimen is 4–6 cwt., though they occasionally attain to 10–12 cwt.; the yield of oil ranges between 6 and 14 gal. usually, but exceptionally amounts to 18 gal. It is obtained from the adipose matter of the cellular substance under the skin, which is boiled down for its extraction. It is free from odour, and has no unpleasant flavour; when well refined, it is clear and limpid. It loses its fluidity at low temperatures. It is so palatable as to be readily taken by stomachs which reject cod-liver-oil; in Australia, it is widely used as a substitute for the latter in medicine, though it differs from it in containing no iodine; it is also employed in lieu of butter, both as an article of diet, and for cooking. Its wholesale value at Perth, W. Australia, is 10*s.* a gal.

Egg-oil (Fr., *Huile d'œufs*).—There are several methods of preparing an oil from the yolk of eggs. (1) The yolks of new eggs are evaporated in a silver saucepan with constant stirring until the oil exudes on pressing the mass between the fingers; this is then enclosed in a bag made of ticking, promptly pressed between heated plates, and filtered while hot. This process is preferable to all others when the oil is to be applied to chaps on the skin; the product is very sweet. (2) The yolks are cooked in a water-bath, with unceasing agitation to hasten the evaporation; they are kept over the fire till, the oil commencing to separate, they have assumed the appearance of broth; they are then left to cool; they are next put into a flask with some ether, and after 24 hours, are poured into a displacer; the mass is there left to drain, and is exhausted with fresh ether; the etherized liquors are distilled; the product is a yellow oil, mixed with viscous matter; the mass is heated to separate the latter, which isolates itself, and the oil is pressed through fine linen, or filtered hot. The oil thus prepared is sweet, provided that well-rectified ether has been used. As it turns rancid very easily, it is kept in small bottles, tightly corked, stored in cellars. (3) Two parts of fresh yolk of egg are diluted with 5 parts of water; the liquid is introduced into a vessel with a ground-glass stopper, and 1½ part sulphuric ether is added; the vessel is occasionally well shaken during 7–8 hours. On standing, the ether charged with oil comes to the surface; it is decanted and distilled; the residue retains a little ether and animal matter; it is treated with concentrated boiling alcohol, and filtered; the alcohol is distilled, and to ensure the removal of every trace of alcohol, ether, and water, the oil is kept in the water-bath; it is filtered hot; it is sweet, and of a yellow colour. If the ether solution of the oil does not separate well from the rest of the liquid, a very slight heating will effect the purpose.

Egg-oil is semifluid at ordinary temperatures, and of a beautiful deep-yellow colour. It has an agreeable odour, and a very pronounced sweet flavour of yolk of egg. It commences to solidify at 8°–10° (46½°–50° F.). It easily becomes rancid, and loses its colour by long keeping. It has been used for application to chapped skin, and on the pustules of small-pox. It is most largely prepared probably in Russia, whence many samples were shown at the Exhibition of 1862. The best qualities are considered far superior to olive-oil for cooking purposes; the impure and very yellow qualities are chiefly manufactured into the celebrated Kazan soap, used by the luxurious classes as a cosmetic. It is sometimes adulterated by means of a fatty oil coloured with turmeric. The fraud is discovered by the mass remaining solid at 8° (46½° F.), and by its giving a soap wanting in consistence.

Herring-oil.—A species of herring (*Clupea pontica*), which is sold in Russia as "Astrakan herring," is turned to account for its oil in Russia and Japan. It is estimated that on the Volga about 100 million of these fish are sacrificed annually for their oil, no use being made of the flesh. During the 3–4 weeks that the fish are arriving in shoals, some 100,000–250,000 *poods* (of 36 lb.) of oil are made. The herrings are placed in open casks containing about 1000, and boiling water is poured over them. After several days, putrefactive fermentation sets in, and the oil commences to escape from the cells; a day's duration of this fermentation suffices to determine the separation of the oil, which floats on the surface of the mass, and is skimmed off. The Japanese extract oil from the herrings caught on the coast of Yesso and the north of Nipon. The principal market for it is Hakodadi, where the value is about 48–56*s.* a *picul* (133⅓ lb.).

Horse-grease or Mares'-grease.—Quantities of this article are shipped from S. American ports. It has about the same consistency as ordinary commercial American lard, and has practically a like value for the purposes of the soap- and candle-maker.

Houlican- or Oolachan-oil.—An oil, which forms an indispensable necessary to the aboriginal inhabitants of British Columbia and Vancouver's Island, is afforded by a little fish (*Thaleichthys pacificus* [*Osmerus* sp.]) closely resembling a smelt or sprat. The fish appear on the coast in April and May, and ascend the rivers in millions to spawn. During their run, which lasts about 3 weeks, countless numbers might be caught. By warming over a slow fire, or heating in water, they yield an abundance of oil, which, when properly filtered, is pellucid, of pale-yellow colour, odourless, and possesses a pleasant flavour. The natives consume it in immense quantities, as we do cod-liver-oil, and with great benefit in the consumptive diseases to which they are subject. It is just coming into general commerce, is of great importance in local trade, and might be procured in very large quantities. The fish are said to be so rich in oil as to burn like a candle when ignited.

Lard (Fr., *Axonge, Saindoux, Graisse de Porc*; Ger., *Schmalz*) **and Lard-oil.**—The fat of the pig, freed from the cellular tissue in which it is contained, is known as "lard." The pieces of adipose tissue are sometimes salted a little to keep them sweet, and are stored in barrels. They are scored and sliced till they do not exceed about 1 in. in diameter, and thrown into caldrons. The common method of "rendering" the lard among very small fat-melters is by means of boiling with water in an open cast-iron vessel exposed to the direct heat of a fire. The use of a steam-jacketed pan and injected steam, as described on p. 1447, is universal in the great American centres. Whatever plan be pursued, the oil is liberated from the tissues, and forms a layer on the surface of the mass; it is drawn off while still warm and liquid, and received in the vessels in which it is to be stored and transported. These vessels are bladders in the case of superior qualities, and little wooden kegs for inferior sorts. The fat immediately surrounding the kidneys yields the best and purest lard. This, and that which is obtained in flaky layers between the flesh and the skin of the animal, is known as "leaf" lard, and is kept separate from the rest, being much more valuable—harder and less fusible. Second-quality lard (which in reality, is the ordinary commercial first quality of wholesale quotations) is used for the production of lard-oil; the third quality, from trimmings which have become slightly tainted, is employed for making low-grade oil or for soap. The best pure lard should be moderately firm and white; the degree of firmness entirely depends upon temperature and the molecular condition [unless stirred while cooling, or exposed to very great cold in a refrigerating-room, it is usually "seedy" and sloppy, even at as low a temperature as 10° (50° F.)]; when melted, as clear and transparent as water; completely free from taste and smell; liquefiable at about 100° (212° F.) without ebullition, or affording a particle of deposit; and containing never more than 2 per cent. of either water or salt (good American lard has no salt, and not above 0·5 per cent. of water). Its melting-point ranges from 42°·6 (108°·6 F.) to 44°·6 (112°·2 F.), and averages 43°·6 (110°·4 F.). Its composition, according to Braconnot, is 38 per cent. of stearine and margarine, and 62 per cent. of oleine; 100 parts of it by saponification yield 9 parts glycerine and 94·65 parts margaric and oleic acids. The solidifying-point of the fatty acids of lard is about 41° (106° F.). Lard dissolves in 36 parts boiling alcohol at 0·816 sp. gr. According to Dr. Hager, the sp. gr. of lard is 0·931–0·932 at 15°–16° (58°–60° F.) when fresh, and 0·940–0·942 when old.

Lard is extensively adulterated, particularly keg-lard manufactured in England, Irish being seldom so treated. American lard seems to be commonly selected for adulteration after its arrival in this country. It is melted with a little water in false-bottomed copper pans, through which circulates steam. The dirt and foreign matters fall to the bottom, and the clear fat is withdrawn into a wooden vessel, where it is stirred in contact with cold water; it is then ground with a thick paste of potato-starch, mixed with a little potash-alum and quicklime, which seem to facilitate the absorption of the water and starch by the fatty matter. The quantity of alum used is such as to leave a small excess, to prevent the mildew attacking the starch. It also helps to increase the lightness and whiteness of the pastry in which the lard is used. Other saline matters, as salt, and the carbonates of soda and potash, are likewise used. The addition of a little mutton tallow to lard is very common, especially in warm weather, to correct the softness of the article. Really good lard is seldom sophisticated, as its market value is much more likely to be reduced than augmented thereby. The frequent adulteration of American lard is owing to its inferior quality and excessive softness, much of it being the entire fat of the pig melted down; some means of rendering it firm is actually necessary.

"Lard-oil" is prepared by placing the lard in woollen bags between wickerwork and the plates of hydraulic presses, where it is left for about 18 hours under a pressure of about 10 cwt. a sq. in. in the cold. The oil or liquid portion (oleine) is thus expressed in a pure, colourless, and limpid state, in the proportion of 62 per cent. of the weight of lard. It remains liquid even in the presence of great cold. It is largely used for adulterating olive-oil in France, and sperm-oil in the E. States of America; it is esteemed as a lubricant, and is said to be also used for illuminating. In Cincinnati, there are some 40 manufactories, turning out about 1½ million gal. of this oil annually. The production of lard-oil in the United States in 1875 was 8,552,583 gal.

The lard produced in the United Kingdom is chiefly Irish. Of European countries, Russia, Hungary, and Servia hold the foremost position. Hungarian lard is supplied to the whole Continent; many of the pigs are so lean as to be useless for food, and some establishments in Budapest boil down ½ million yearly for the lard alone. Pig-keeping is the leading industry of Servia, and large supplies of lard may be expected from that country in the near future. At present, America is the chief producer. In the United States, the average yield of lard from each pig was 25 lb. in 1862, and 37⅓ lb. in 1874. The total exports of lard from the United States in 1870 were but 35,809,000 lb.; in 1878, they reached the enormous figure of 342,668,000 lb., value 30,014,000 dollars (of 4*s*.), but fell to 326,659,000 lb. in 1879. The exports of lard from New York in 1879 were 2,412,395 cwt.; and of lard-oil, 1,236,442 gal. Philadelphia exported 12,915,027 lb. of lard, and 268,479 gal. of lard-oil, in 1879. Baltimore exported 21,262,610 lb. in 1878, 26,950,519 lb. in 1879, and 34,797,502 lb. in 1880. New Orleans despatched 1350 tierces in British ships in 1880. The Canadian exports of lard have fallen from 38,048 cwt., value 94,509*l*., in 1876, to 4509 cwt., 7801*l*. in 1879. Denmark, in 1878, exported 160,066 lb. of lard and grease to Great Britain.

Malabar oil.—The ambiguous term "Malabar" oil is applied to a mixture of the oils obtained from the livers of several kinds of fish frequenting the Malabar coast of India, and the neighbourhood of Kurrachee. The species chiefly caught are *Rhyncobatus pectinata*, *R. lævis*, *Galiocerda tigrina*, and *Carcharias melanopterus*. This last is found in considerable numbers, and is taken principally in October–November, the livers being then much more developed, though the quality of the oil is about the same at all seasons. The most esteemed livers are firm and rosy-coloured, the white and flabby ones are inferior. The livers are cleansed, cut up, placed in earthen vessels with enough water to cover them, heated for 15–20 minutes, and then allowed to cool. The oil is skimmed from the surface, poured into earthenware jars, then passed through a sieve; 3–4 days later, it is filtered through a thick strainer, to separate the abundantly deposited stearine, and this operation is repeated 4 times, at intervals of 20–25 days, after which, the oil remains clear, exhibiting a fine straw colour, and smelling much like cod-liver-oil. Thus prepared, it is employed medicinally. The inferior oil is compounded with that obtained from the livers of the other kinds by heating, without previous washing or picking, and without any subsequent purification; the whole is used for lighting, and other domestic purposes, and might be utilized for soap-making.

Manatee-oil (Fr., *Huile de Lamantin*).—There are several species of *Manatus*, found in the rivers of Central and S. Africa, and in the estuaries, bays, and inlets of the W. Indies, and the coasts of Mexico, Brazil, and Guiana. Beneath the skin of these animals, is a layer of fat, generally about 1 in. thick, and which is boiled down to afford an oil used for lighting and cooking, each animal yielding 5–25 gal., according to its size and condition. By exposing the oil to the sun, it acquires a fine odour and flavour, and does not become rancid. The fat of the tail has a harder consistence, and, when boiled, is more delicate than the other.

Menhaden-oil, Straits or Bank Oil.—A fish eagerly sought for its oil on the Atlantic coast of America is the "menhaden" or "porgie" (*Alosa* [*Brevoordia*] *Menhaden*), a member of the herring family, about 8–14 in. long. The fishery is carried on all along the coast from Maine to Maryland. The fish leave the Gulf Stream and strike the coast of New Jersey in April, reaching the coast of Maine in May–June, and remaining till October–November. They migrate in enormous schools, and are caught in seines, carried by the fastest and smartest yachts. Very few of the fish are sent to table; nearly all are boiled down for their oil. This is performed in the following manner. The fish are shot into receiving-tanks situated outside the building; thence a sliding door opens into the boiling-tanks, which are long, watertight, uncovered boxes, of varying capacity, provided with a coil of perforated pipe for the admission of steam, and a plug-hole for the exit of the liquid after boiling. Some water is put into the tanks ready for the fish, and as soon as the latter have been introduced, steam is turned on, and the whole mass is boiled for 20–40 minutes. When the cooking is completed, the liquor, containing a portion of the oil of the fish, is drawn off into settling-tanks, for the recovery of the oil. The "pomace" or cooked fish is raked into "curbs," perforated cylinders fitted with hinged bottoms, and these, when full, are placed under hydraulic presses. Pressure is applied so long as water and oil continue to escape from the mass. The remaining solid matters, called "scrap," are treated for the preparation of a fertilizing compost (see Manures, p. 1257). The oil and water pass by gutters into settling-tanks, where the oil soon rises to the surface, and is skimmed off, or allowed to escape over a separating partition.

The oil is still crude, and requires clarifying and bleaching before it becomes a saleable commodity. This is effected in several ways. It is first boiled, to free it completely from water. It is purified from solid matters by running it into filter-bags suspended over casks, and then subjecting it to pressure in bags, the oil escaping while the sediment remains in the bags. This refuse, termed "foots," is bleached, and used for soap-making. The oil thus refined is termed "straits," and is ready for barrelling. "Bank" oil is an inferior grade. Bleaching is sometimes performed by exposure to the sun in shallow tanks, having glass covers to exclude dust when a superior quality is desired. The yield of oil is at its maximum in September, when a barrel (250) of fish gives about 4½ gal. of oil. The average product of 1000 fish is 13–14 gal. of oil. The total catch in 1878, an average year, gave 80,000 barrels of oil, 23,815 of which (644,762 gal.) were exported under the denomination of "fish-oil," and 45,000 were locally consumed. The exports in 1879 were 613,663 gal. Its principal application in America is for tanning and currying purposes. In France, it is largely employed as a substitute for cod-liver-oil, costing at Havre only about 45 *fr.* a 100 *kilo.*, while the latter fetches 50–53 *fr.* In this country, it is said to be often passed off as olive-oil, and that considerable quantities of it are mixed with linseed-oil for painters' use. The rapidity with which it oxidizes, and its good body, render it not unsuitable as a vehicle for paint; the same causes make it inadmissible for lubricating.

Neats'-foot-oil (Fr., *Huile de pieds de bœuf*).—From "ox-feet," the feet and hocks of neat cattle cut off about 18 in. above the hoof, is obtained a valuable oil, known as "neats'-foot." Its preparation, which is usually performed by tripe-dressers, is as follows. The "feet" as received are denuded of skin, and slit up longitudinally, by a knife passed between the sections of the hoof and continued between the long bones. Near the hoof, is a small mass of soft fat, which is scooped out with the knife, and set aside for the preparation of the best quality of oil. The hoofs are washed in cold water, and then boiled in open pans set in brickwork, and heated by a fire beneath. A certain quantity of oil is thus boiled out of them, and when skimmed off, forms an inferior grade of neats'-foot-oil. After about 3 hours' boiling, the tissues between the horny hoof and the last digit bone are sufficiently softened to allow of the latter being easily scooped out of the hoof with a knife. These "cores," consisting of bone, gelatinous matter, and fat, together with the small pieces of fat previously alluded to as being removed by the knife before boiling, are put into a separate pan of fresh water, and all boiled together for the extraction of the oil. This forms the best kind of neats'-foot-oil. It is reckoned that 10 "feet" will give about 1 qt. of oil. It is made in most large towns, and some quantities are shipped from the River Plate and the Falkland Islands. Philadelphia exported 1125 gal. in 1879.

This oil is usually yellowish or greenish in colour, but that from Buenos Ayres is often colourless. It is odourless when fresh, and of agreeable flavour. It is limpid, and remains so below a temperature of 0° (32° F.). Its density at 15° (59° F.) is 0·916. On standing for a short time, a proportion of solid fat separates out, and may be filtered off. Its limpidity, which is intensified in the oil obtained from Buenos Ayres, causes it to be largely employed for lubricating, especially clocks and bearings exposed to the cold. It is very rarely found pure.

Niin-oil.—An insect belonging to the genus *Coccus*, and which has been named *C. adipofera*, affords an oil having considerable economic use in Central America. It feeds on the resinous sap of a species of *Spondias*, whose local cultivation is so easy that even thick cuttings germinate quickly in almost any soil. The breeding of the insect is dependent simply upon the multiplication of this tree, which is already under extensive cultivation all over the tropics of continental and insular America. The female insects, which yield the oil, adhere to the trees by means of their beaks, existing in such large numbers that they frequently cover every portion of the plant. The oil is extracted from the insects by broiling or boiling them, and amounts to 26–28 per cent. of their weight. It is bright-yellow to yellowish-brown in colour, and possesses a peculiar odour. When recently melted, it is homogeneous, but soon becomes granular and lighter-coloured. Its melting-point is about 49° (120° F.); when melted, it remains fluid at even 27°–29° (80°–85° F.). Cooled to −12° (10° F.), it becomes hard and brittle, like suet. At ordinary temperatures, it is thick and pasty, like lard, and its sp. gr. is about 0·92. It is insoluble in alcohol, but freely soluble in hot and cold ether, forming a yellow oily liquid; it is very soluble in turpentine, producing an oily liquid of special value for mixing delicate oil-colours; it is also freely soluble in benzine and chloroform. It is a thorough drying oil, though its absorption of oxygen is slow, and is not hastened by boiling with oxide of lead. Its composition resembles that of ordinary animal fats. Its saponification is unusually difficult, and only effected after prolonged boiling with strong soda-lye. When melted in a porcelain dish, and the resulting oil is exposed to a temperatere of 121°–177° (250°–350° F.) for an hour, or till a considerable part has evaporated, the residue assumes a tough, flexible, varnish-like condition, is no longer soluble in turpentine, and but little affected by heat and cold. This, ignited with turpentine, affords a thick, yellow gum or oleo-resin closely resembling a thick solution of indiarubber, possessing remarkable adhesiveness, and retaining the semi-fluid consistency for several days. When the turpentine solution of the oil is exposed in thin strata to the air for some days, it acquires the properties of a resinous varnish, almost equal to fine shellac varnish, very elastic and hard.

The present native uses of this remarkable oil, which has yet to find its way into general commerce, are almost confined to its admixture with the pigments employed by the Indians and Mestizos of the peninsula of Yucatan, and in the vicinity of Vera Cruz, for adorning small household articles; it is also kept as a drug by the apothecaries of Yucatan, and is generally employed as a drying oil. In the industrial arts, its drying solution in turpentine will make it valuable to artists; it remarkably brightens colours prepared with it. Of greater commercial importance, perhaps, is the resinous varnish which it affords when treated as described above. The turpentine solution of niin-oil renders even the most porous filter-paper absolutely impervious to water. Articles to be waterproofed with it might be saturated in the solution, and then heated in an oven till the grease volatilizes. The coating then defies most solvents of oils.

Porpoise-oil (Fr., *Huile de Belouga, de Marsouin*).—The term "porpoise-oil" embraces the oils obtained from the black porpoise (*Delphinus phocæna* [*Phocæna communis*]), the white whale (*Beluga catodon* [*Phocæna leuca, Delphinapterus leucas*]), the grampus (*Phocæna orca*), and the black-fish, which last name is very variously bestowed (see Blackfish-oil, p. 1361).

The first is very abundant in the Atlantic, and is found in considerable numbers in the Mediterranean and Black Sea. Its systematic pursuit is carried on by the natives of Lazistan, who generally take it in nets, but occasionally shoot it. This fishery has its centre at Trebizond, and commonly affords 700,000 lb. of oil in a year. A portion is used locally for illuminating purposes, and the remainder finds a ready sale. The quantities exported by steamer from Trebizonde in 1878 were:—1400 cwt., 1750*l.*, to Constantinople; 524 cwt., 655*l.*, to Austria and Germany; 514 cwt., 642*l.*, to Russia; total, 2438 cwt., 3047*l.* Large schools of porpoises are met with on the Danish coasts, and frequently 1500–2000 are caught in the Little Belt.

This creature and the white whale are taken together in great numbers in the St. Lawrence, Canada, and occasionally in the Bay of Chaleur, parts of New Brunswick, and the Hudson Bay territories. They are surrounded by enclosures made of light flexible poles driven into the beach, within which they are speared and harpooned from boats. In the bays of the Polar Sea, on the coast of Kanin, near Mesen, in the White Sea, and at the mouths of the Petschora, they are killed most numerously by harpoons in June–July, whole fleets of boats being engaged. The full-grown animal attains a weight of 2500–3500 lb., and gives some 400–450 lb. of oil, which is more esteemed than that of either the seal or the walrus. The oil is inodorous, and gives a brilliant light; it congeals only in intense cold, and its softness renders it valuable for lubricating and leather-dressing.

The oil from the head of the grampus is thought to be a superior lubricator to any yet obtained from the porpoise and the black-fish. This cetacean occurs much more rarely than either of the animals just described.

Sardine- and Louar-oils (Fr., *Huile de Sardine, de Louar*).—Several species of sardine afford an abundance of oil. The ordinary sardine (*Clupea Sardinus*) of the Mediterranean is too important as a food-fish to be generally sacrificed for its oil, yet a large quantity of the latter is made from damaged and refuse fish. More important as oil-producers are the *louar* (*C. Neohowii*), *C. lemuru*, and *C. palasah*, of the Indian and Malayan Seas. They are migratory, reaching the shores in immense shoals in August–September, and becoming sufficiently fat in October–November. They are taken in nets, and treated with boiling water to separate the oil, the exports of which, from Cochin, sometimes amount to 150,000 cwt. in a year.

Seal-oil (Fr., *Huile de Phoque*; Ger., *Seehundsöl*).—The principal species of seal are *Phoca fœtida*, *P. vitulina*, *P. barbata*, *P. annelata*, *P. groenlandica*, and *Cystophora cristata*. *Phoca caspica* is found only in the Caspian Sea, where it is hunted for the sake of its oil, which is consumed in Russia. All the other species are widely distributed throughout the north polar regions of both hemispheres, and their chase, for the value of their oil and skin, forms the most important branch of the so-called "Arctic fishery," extending from Iceland eastwards to Scandinavia, along the northern coast of Russia, especially about the mouths of the Dvina and Mesen, and the eastern shores of the White Sea, across to Alaska, throughout the bays and inlets of arctic America, and on the coasts of Greenland and Spitzbergen.

Newfoundland may be considered the centre of the seal districts, and stands foremost on the list in point of production. The species chiefly resorting to this coast are the two largest—the hooded seal (*Cystophora* [*Stemnatopus*] *cristata*), and the harp seal (*Phoca groenlandica*). Their whelps are born in January–February on the Labrador ice-fields, and this "whelping ice" is floated southwards, and appears off the Newfoundland coast after the middle of March. The young seals, not taking to the water till they are three months old, are easily caught; their skins are stripped off with the blubber attached, and the carcases are left on the ice. The produce is sorted into five qualities:—"young harp," "old harp," "young hood," "bedlamer" (1-year-old hood), and "old hood"; the most rich in oil is "young harp."

The average take of successful vessels is about 2000 seals, though it sometimes reaches 8000, and, in extraordinary seasons, individual ships have secured 10,000–20,000. Out of 400 vessels yearly engaged in sealing, not more than 60 make remunerative voyages. It is thus a speculation rather than a steady industry. So soon as the vessels have disembarked their first cargo, they start on a second hunt. This time they rarely take many young seals, as these have escaped to the water by about the 1st April; but they pursue the old ones, sometimes shooting them on the ice "pans," sometimes finding a herd cut off from the sea, and knocking them on head with clubs. The exports of seal-oil from Newfoundland have risen from 1605 tuns, value 76,247*l.*, in 1864, to 5905 tuns, value 147,625*l.*, in 1878; in 1871, they reached 6943 tuns, value 202,504*l.*

On the Greenland coasts, and especially between latitudes 60° and 61° N., *P. fœtida*, *P. vitulina*, *P. groenlandica*, *P. barbata*, and *Cystophora cristata*, are abundant, more particularly the last-named. The catch amounts to some 89,000 annually. The total production of blubber, including that from white whales, &c., is estimated at 2050 tuns yearly, of which 500 are used by the natives for lighting, and 100 for food. Harpoons, lances, guns, and nets are employed in the chase.

The 15 Norwegian vessels engaged in sealing in 1879 procured 30,000 crested seals or "hoods" (*Cystophora cristata*), and 55,000 of other kinds, old and young. The yield of oil was reckoned at upwards of 17,000 barrels. The price was as low as 36–48 *kroner* (of 1*s.* 1½*d.*) a barrel, whereas a few years since it was 70 *kr.* in the German markets. The exports of seal-blubber from Sweden and Norway in 1879 were 16,938 *hectol.* (of 22 gal.). It is hardly possible yet to judge of the effects of the lately made law for the protection of the seals in the Arctic Seas during the season after they have cast their young; but there is good reason to expect that it will somewhat postpone their extermination, which at one time appeared immediately imminent.

Of the extent of the Russian seal-harvest in the White Sea and thereabouts, no accurate statistics are procurable, but the catch is approximately said to be only half that of the Caspian. In the latter, about 140,000–160,000 *poods* (of 36 lb.) are obtained every year.

The average quantity of oil afforded by 1000 seals is roughly estimated at 10 tuns. In the Russian fisheries, *Cystophora cristata* is reckoned to yield 360 lb. of blubber; *Phoca groenlandica*, 160–240 lb.; *P. annelata*, 120 lb. In Newfoundland, *P. groenlandica*, old, gives an average of 288 lb. of blubber, producing 22½ gal. of oil; same species, young, 225 lb. of blubber, 22 gal. of oil; *Cystophora cristata*, young, 230 lb. of blubber, 21 gal. of oil; same species, bedlamer, 246 lb. of blubber, 21½ gal. of oil. The skins and blubbers brought in by the hunters are stripped apart, and undergo separate treatment. The latter are generally put into wooden cribs, with pans beneath to catch the exuding oil, no artificial heat being employed. The oil which runs out during the first 2–3 months is called "pale seal," and forms 50–70 per cent. of the whole. As putrefaction sets in, the oil becomes darker and more offensively odorous. The solid refuse and the clippings of the skins are boiled to yield further quantities of "boiled seal-oil." This old process, though still widely surviving, is superseded in the best factories by steaming the blubber, by which all the oil, of a uniform and much better quality, is extracted in 12 hours. (For Fur-seal-oil, see p. 1375).

Shark-oil (Fr., *Huile de Requin*).—The seas of N. latitudes are inhabited by four species of shark—the "Greenland shark" (*Scymnus borealis* [*Squalus glacialis*]), the "basking shark" (*Selache maximus*), the "picked dog-fish" (*Squalus acanthias*), and the *kulp* or *hoastorsk* (*Squalus spinax niger*); the livers of these fish afford valuable oil.

The first-named numerously frequents the banks which may be traced in a line for nearly the whole length of the W. coast of Norway, at distances varying from 50 to 100 miles from the land; in greater abundance, however, on that portion which fringes the coast of Nordland and Finmark, as far as the North Cape, and between the latter and Cherry or Bear Island. They are met with, moreover, throughout the whole North Sea and Arctic Ocean, as well as in most of the fjords on the W. coast of Norway, at 100–200 fathoms, and their pursuit forms an important and remunerative branch of the Icelandic fisheries during a portion of the year. Formerly the Norwegian shark-fishery was confined to the immediate vicinity of the coast; but of late it has been more especially and lucratively prosecuted on the banks commencing at about 68° N. lat. Shark-fishing is now carried on vigorously by the Russians in the bays about the peninsula of Kola, Lapland. The fish are taken by means of large, strong hooks, baited with fish or about 1 lb. of seal-blubber, taken from seals caught at Spitzbergen and then salted while fresh. In Iceland, horse-flesh is preferred before all other bait. Porpoise-blubber sometimes replaces seal. The fishery begins about the end of September, and continues through the winter till the end of February. From N. Iceland, it recommences as soon as the drift-ice will permit, say March–April. The length of the fish varies from 10 to 18 ft. The value depends almost solely upon the size, quantity, and quality of the liver, which yields 15–60 gal. of fine oil. In summer, the livers are almost valueless. The flesh and skin are usually thrown away, though possessing considerable value.

The "basking shark" is found all along the Norwegian coast, from Ryvarden (59° 31′ N. lat.) to Finmark. Its pursuit was long followed with such activity and success as to afford the staple support of those engaged in it, but of late years decreasing numbers have much reduced its importance. Its chase resembles that of the whale rather than of other kinds of shark, as it cannot be baited nor enticed. Towards the conclusion of the dog-days, when the sea and the air are at their highest temperature, this fish makes its appearance on the coast; it lies perfectly still near the surface of the water, apparently basking in the sun, and follows leisurely after the boats which are in quest of it. It is thus struck by harpoons, such as are used for taking sturgeon. In size and condition it varies much; the prevailing length is 30–35 ft., increasing occasionally to 40 ft. The size of the liver depends mostly on the condition of the fish; the usual quantity of liver taken from a fish is 4–7 barrels, occasionally 10–16, and in very rare instances 24; 6 barrels of good liver should yield 5 barrels (of 30 gal.) of oil. The same fish is found in Indian waters, and is there called *mhor*. It is harpooned in great numbers by the Kurrachee fishermen, one estimate stating the annual catch at 40,000. The size here varies from 40 to 60 ft. in length, and the usual yield from one liver is 8 barrels of oil, of very low sp. gr.

The picked dog-fish, which was formerly very abundant along the whole coast from Gothenburg, is now pursued during the entire summer, from the Naze to the North Cape, in the Norwegian fjords as well as along the coast. About midsummer it swims near the surface, and is taken either by nets or lines. The liver is exceedingly rich in very fine oil.

The *kulp* or *hoastorsk* is met with in all the deep fjords along the Norwegian coast, where it does much mischief by nibbling off the baits from the deep-sea cod-lines. It is taken in numbers at a time, by lines with 10–12 hooks baited with tainted fish, in 60–100 fathom water. It travels in shoals, and feeds at night. Its liver is unusually rich, and yields a superior oil.

Sharks are caught in great numbers on the shores of New Zealand, during November–January, by the natives, who use them for food. A premium for the capture of sharks offered by the Victorian Government has promoted this branch of fishing among the sailors of Hobson's Bay, and very large numbers are now taken. They are also very common in Sydney Harbour, New South Wales.

Shark-oil is largely used in tanneries. It is also extensively passed off surreptitiously as cod-liver-oil and is probably but little less efficacious; the oil and liver are both esteemed as food by the Icelanders.

Sod-oil.—The term "sod"-oil is applied to the oil which has been fulled into skins during the operation of tanning, and has been subsequently washed out with soda. English sod-oil comes chiefly from deer- and sheep-skins, and is largely adulterated with gelatine from green sheep-skins. The purest and best sod-oil is from France, where olive-oil is employed in the tanning; the next is English, where cod-oil has been used; then comes American, where the currying has been done with "fish-oil" (menhaden-oil). This last now fetches the highest price. Sod-oils are much esteemed for lubricating delicate watches, &c.

Spermaceti or Head-matter (Fr., *Spermacéti, Blanc de Baleine*; Ger., *Spermaceti, Walrath*).—"Spermaceti" is chiefly the solid wax-like portion of the sperm-oil, or so-called "head-matter," found in the head of the "sperm-whale" or *cachalot* (*Physeter macrocephalus*), an inhabitant of the Pacific and Indian Oceans. On the right side of the nose, and upper portion of head of this species, is a triangular-shaped cavity, termed the "case," enveloped by an enormous mass of sinewy gristle called "white horse," which resists even a sharp axe. The case is filled with liquid "head-matter," consisting of spermaceti and oil; the whalers make an opening into the case, and remove the contents by a bucket, as many as 45 barrels being occasionally filled. This matter is carefully boiled alone, and placed in separate casks, and is commonly known as head-matter. It is of a yellow colour, and its consistence varies with the temperature. It undergoes a purification for the purpose of candle-manufacture, in which it is employed (see Candles, p. 589). The refined article is transparent, smooth, brittle, insipid, inodorous, and very difficultly saponifiable; its sp. gr. is 0·943 at 15° (59° F.); it is fusible at 45° (113° F.); it is insoluble in water; 100 parts of alcohol of 0·821 sp. gr. dissolve 3½ parts of spermaceti, but deposit about $\frac{9}{10}$ on cooling; it is also soluble in both fatty and volatile oils. It is said to be adulterated commonly with fatty matters, such as tallow, margaric acid, &c. Such falsifications are easily discovered by the saponification of the mass, and by the reduction of the fusing-point.

Similar products are obtained in lesser quantities from the head-cavity of *P. Tursio* and *Delphinus edentulus*, from the bladder of *Balæna rostrata*, and from the oil of *Delphinus globiceps*.

The Tasmanian whale-fishery produced 558 tuns of sperm-oil in 1873, and 342 in 1874. The exports in 1876 were 513 tuns, value 45,248*l.*; and in 1878, 279 tuns, value 17,577*l.* The production in 1869 was 643 tuns. The exports of sperm-oil from New York in 1878 were—911,975 gal. to Great Britain, 49 gal. to N. Europe, and 579 gal. to S. America, E. and W. Indies, &c., total 912,603 gal.; in 1879, they were 1,089,137 gal. The production of spermaceti in the American whale-fisheries was 1,300,959 gal. in 1878, and 1,285,454 gal. in 1879.

Tallow (Fr. *Suif*; Ger., *Talg*).—The cellular tissues of man and quadrupeds contain a concrete fat, the whole mass of tissue and fat being known as "suet." The term "tallow" is applied to this fat when it has been liberated from the tissue. Commercially, tallow is obtained almost solely from the ruminant animals, sheep and neat cattle, and is produced chiefly in the essentially pastoral portions of the globe. In many cases, the animals are (or were) reared more for the sake of their tallow than their flesh, and, in Australia, millions of them have been boiled down as they were killed, the boiled flesh being used for pig-feeding or manure. Recent improvements in transporting meat will doubtless prevent the recurrence of such a wasteful process, though the tallow may retain its importance as a commercial product, and will be prepared at the places where the animals are killed for transportation in cold chambers.

The "rendering" of tallow, or its separation from the cellular tissues in which it is confined, is performed on the large scale exactly the same as lard-rendering, described at length under the section on improved methods of extraction (see p. 1447). Occasionally mechanical power is employed to facilitate the operation, the suet being first passed through a specially constructed chopping-machine. The rendering is also greatly assisted by the addition of dilute sulphuric acid to the mass, say 1 per cent. of the acid and 20 per cent. of water on the quantity of tallow present; but there is a great, and to some extent well-founded, commercial prejudice against tallow in which any chemicals have been used during its preparation. The melted tallow is strained to free it from membrane. The nature and qualities of tallow vary greatly. The constituents are stearine, oleine, and possibly margarine; stearine predominates, but its proportion fluctuates with the species, age, and sex of the animal, and the portion of its body which afforded the suet. Beef-tallow usually contains less stearine than does either mutton- or venison-, and mutton-tallow is always whiter than beef-tallow, but S. American beef-tallow presents the curious exception of containing *more* stearine than S. American mutton-tallow. The hardness and melting-point have an equal influence upon the value of the tallow, and exhibit the same want of constancy under similar changes of condition. The degree of solidity much depends upon the food, increasing as the latter is drier. Pure tallow is white and almost tasteless, but that imported has a yellow tint. It is classed according to its suitability for candle- or soap-making, for which purposes it requires to be refined (see Candles, p. 579).

The term "beef"-tallow includes that of oxen, cows, and bulls; the former is much softer than the two latter. After melting, it commences to solidify at 37° (98½° F.), and its temperature then rises to 39° (102° F.); it dissolves in 40 parts alcohol of 0·82 sp. gr. Veal-tallow melts easily in the fingers, is very soft, and quickly becomes stale. "Mutton"-tallow comprises that of rams, ewes, bucks, and she-goats. On remaining some time exposed to the air, it acquires a peculiar odour. After melting, it commences to solidify sometimes at 37° (98½° F.), when its temperature rises to 39° (102° F.); at other times, it solidifies at 40° (104° F.), and its temperature rises to 41° (106° F.). It dissolves in 44 parts boiling alcohol of 0·82 sp. gr. Dr. Hager thus states the sp. gr. of tallows at 15°–16° (58°–60° F.):—Beef, 0·925–0·929; mutton, 0·937–0·940; beef and mutton mixed in equal proportions, 0·936–0·938. "Town tallow," "kitchen stuff," or "pot-grease," is the waste fat produced in culinary operations, and is consumed by soap-makers. Tallow is largely adulterated with starch, china-clay, ground limestone, and sulphate of barium; also with fats having a lower degree of hardness, especially "bone-fat" (see p. 1361). Mineral adulterants are easily discovered by simple solution of the mass; starch is detected by the iodine test; and inferior fats lower the appearance and consistence of the sample, and thus indicate their own presence.

In commerce, tallow occupies a very important place. Russia exports immense quantities, chiefly from the ports of Cronstadt, Odessa, and Taganrog. A dozen years ago, Russia's annual production was reckoned at 160,000 tons, half of which was consumed locally. The home consumption has since much increased. Thus the exports were 3,249,802 *poods* (of 36 lb.) in 1866; they gradually fell to 411,585 *poods* in 1875, recovered to 1,110,729 *poods* in 1877, and dropped back to 619,301 *poods* in 1878. Russian tallow is nearly all beef, and comes chiefly from Siberia and the Ukraine. It is transported in casks of 300–400 *kilo.* The commercial quotation of "P.Y.C. tallow" is a fiction, and does not regulate the market-price of tallow; it is a mere speculative medium, thousands of casks being bought and sold that have no existence whatever. Russian tallow has lost much of its hold on the market, and now forms but a small item in the total consumption in this country, notably in the case of the soap- and stearine-makers, for whose purposes it is less suited than for "dips." The States of S. America afford very large quantities of tallow from the carcases of animals slaughtered principally for the sake of this product and their skins, bones, and horns. It is generally known as "River Plate" tallow, and is mostly shipped from the Rio de la Plata. It has a strong-yellow colour, but is of good quality; it first arrived in serons of hide, but now comes in old wine-casks—pipes and half-pipes. The United States ship considerable quantities of tallow to Europe, chiefly from New York and New Orleans, in barrels of various sizes. The total exports were 85,506,000 lb. in 1878, and 99,964,000 lb. in 1879; in 1869, they were only 20,535,000 lb.; in 1874, 101,756,000 lb. The shipments from New York were 70,807,600 lb. in 1878, and 67,016,100 lb. in 1879. Of the shipments in 1878, 31,775,300 lb. went to Great Britain, 18,474,500 lb. to France, 16,687,100 lb. to N. Europe, 2,288,000 lb. to other Europe, and 1,582,700 lb. to S. America, E. and W. Indies, &c. Philadelphia exported 9,201,599 lb. in 1879. Excellent tallow is obtained from Algeria and Morocco, and chiefly consumed in the soap-works of Marseilles. The Chinese port of Kiungchow shipped 924 *piculs* (of 133⅓ lb.), value 1850*l.*, in 1877; 1906 *piculs*, 4007*l.*, in 1878; and 2688 *piculs*, 6225*l.*, in 1879. The exports and re-exports from Hankow in 1878 were 2776 *piculs;* the exports thence in 1879 were 564¾ *piculs*, value 1114*l.* Pakhoi, in 1879, exported 324*l.* worth. Shanghae, in 1879, imported 301½ *piculs* of foreign tallow from foreign countries, and 1423½ from Hong Kong and Chinese ports, none being re-exported; and of native tallow, the imports from Chinese ports were 815⅓ *piculs*, and from Hong Kong 433¾, all being re-exported to Chinese ports. Newchwang exported 415 *piculs* in 1877, but none is recorded since. The annual exports (chiefly re-exports) of tallow from Holland amount to 4½–7½ million *kilo.*; in 1879, they were 6,829,000 *kilo.* The Belgian exports (chiefly re-exports) fluctuate between 17 and 26 million *kilo.* yearly, and were 25,871,000 *kilo.* in 1879. The shipments of tallow from New South Wales have fallen from 190,575 cwt., value 311,339*l.*, in 1871, to 61,326 cwt., 98,018*l.*, in 1878; they were 100,390 cwt., 164,561*l.*, in 1877. In the case of Victoria, they have fallen from 13,582 tons, 469,069*l.*, in 1871, to 3298 tons, 103,879*l.*, in 1878. From New Zealand, they have increased from 828 cwt., 1661*l.*, in 1867, to 100,380 cwt., 178,502*l.*, in 1878. From Queensland, they fell from 124,180 cwt., 139,181*l.*, in 1871, to 19,194 cwt., 50,899*l.*, in 1873, and were 43,164 cwt., 73,006*l.*, in 1877. The exports of tallow from Honolulu in 1879 were 239,941 lb., to Germany. The value of the tallow shipped from the Falkland Islands to Great Britain was 4874*l.* in 1878, and 5940*l.* in 1879. The exports of tallow from India fell from 3540 cwt. in 1878, to 870 in 1879. The E. Indian tallow is very strong in stearine, but of bad colour. A similar tallow comes from Turkey; Japan also sends a good quality. The tallow production of the United Kingdom has been estimated at 100,000–120,000 tons yearly.

Tunny-oil (Fr., *Huile de Thon*; Ger., *Tunfischöl*).—The tunny (*Thynnus vulgaris*) is second in importance only to the sardine among the fish caught in the Mediterranean. During May and June, endless shoals of these fish migrate from the Mediterranean, through the Straits of Gibraltar, to the Atlantic, returning in July–August. Those caught during the exodus are much fatter and more valuable than those taken on the homeward passage. The coasts frequented by this fish are chiefly within the Mediterranean, extending without interruption along the Spanish and French coasts from the Straits to Nice, reappearing on the Italian coast between Camogli and Spezia, off the W. side of Elba and Sardinia, near Palermo and the Straits of Messina, around Malta and the Karkaneh Islands, and in the Gulf of Tunis. Outside the Mediterranean, the fish visits the European coast, from the Straits westward to Cape St. Vincent, and occurs less abundantly along the French coast from Yen northwards to Belle Isle. The tunny fishery in the Bay of Biscay is most important at Rochelle, Ile de Ré, and Sables d'Olonne, commencing in July, and lasting till mid-September. The Portuguese fishery is confined to the province of Algarve, the tunny not being found farther west than Sagres; the fish is chiefly taken in the space between the mouth of the Guadiana and Cape Santa Marta from the end of May till the beginning of August, and from the latter point to Albufeira from April till June. The Spanish tunny fishery is concentrated at the mouth of the Guadiana, around Cristina Island, and at Veger, Conil, Chiclana, Rota, Mojarra, and Portil. The catch begins in May, and ends in the last days of August. The Italian tunny-harvest lasts from April till the end of July, and is distributed chiefly thus:—Gulf of Palermo: S. Flia, Solanto, S. Nicola, Trabia; Sea of Milazzo: Oliveri, S. Giorgio, Vaccaro Pepe; W. Coast: Capo Passero; Sardinia: Portoscuso, Portopaglia, Isola piana, Calaviuagra, Flumentorgiu, Alghero, Trabucato, Asinara; Elba: Porto ferrajo, Anfola, Marciana; on the mainland: Birvona and Pizzo, Porto S. Stefano, Camogli, and S. Margherita. It is estimated that in the Gulf of Tunis, some 10,000 tuns are taken yearly.

The fish yields a very large quantity of oil, which is extracted from it by boiling, the operation being performed at the fishing-stations, in the crudest possible manner, and often with sea-water. Generally only the heads, bones, and entrails of the fish are used, in varying stages of decomposition, and it is rare that any trouble is taken to prevent the oil being burnt and smoky. Good tunny oil is of a pale amber colour, and has an agreeable flavour; it possesses more body than any other fish oil, but contains no iodine. By boiling, it assumes a rich broom-yellow hue; and when left at rest in shallow open vessels, it undergoes a peculiar condensation (doubtless an oxidation), commencing about the end of August or beginning of September, and gradually extending till the whole mass becomes solid, and remains so unless heated. It is very commonly adulterated with Bergen and Hamburg inferior cod-oil, with sardine-oil, and with cotton-seed-oil; the presence of each and all of these is manifested by their remaining liquid while the tunny-oil solidifies. It is highly esteemed for leather-dressing, even in its impure and sophisticated state, and is said to be employed as a lubricator, though that must be regarded with doubt. It is put up in casks, and forms an article of trade in Genoa, Sardinia, Spain, and Tunis. The last-named country produces some 30,000–35,000 *kilo.* of the oil annually, and the value of its export in 1871 was 1600*l.* That prepared at Genoa is said to be superior to all others. The industry deserves much greater attention, and is capable of indefinite extension and improvement.

Walrus-oil (Fr., *Huile de Morse*; Ger., *Walrossöl.*—The walrus or sea-horse (*Trichecus Rosmarus* [*Rosmarus obesus*]) is pursued by the Arctic whalers. Some 50,000 are killed every year, but it is reckoned that 3 out of 4 struck are lost through the inefficiency of the projectiles used. On the coast of Danish Greenland, the walrus is met with between 66° and 68° N. lat., but the number killed yearly does not exceed 200. From 20 to 30 gal. of much-esteemed oil are obtained from each animal.

Whale-oil, Train-oil, and Blubber (Fr., *Huile de Baleine*, *de Nordcaper*, *de Rorqual*, *de Jubarte*; Ger., *Walfischspeck*, *Thran*).—The competition of mineral oils for illuminating, and animal and vegetable oils for industrial purposes, and the substitution of various articles for the once almost indispensable whalebone, have caused a gradual and general decline in the whale-fishery. The United States now take the lead in it. Their whaling fleet on 1st January, 1880, numbered 178 vessels, with a total burden of 39,433 tons, nearly all hailing from New Bedford. In the Behring's Straits waters, in 1869, 43 American ships secured 38,275 barrels of train-oil; in 1879, 18 obtained 17,118 barrels. In the Pacific, 40 ships in 1879 got 15,000 barrels. On the Californian coast, are some half-dozen whaling stations, for the capture of "grey-backs" mostly, which are difficult to secure, and not very rich in oil. The best catch is from November to February, when the whales are going south near the land; from May to October, they travel northwards farther at sea. In Hudson's Bay, 7 American vessels in 1870–6 procured 3048 barrels of train-oil. The exports of whale-oil (in gal.) from New York in 1878 were:—348,028 to France, 77,905 to Great Britain, 3050 to S. America, E. and W. Indies, &c., 2228 to Europe, 540 to Scandinavia; total, 431,751. Philadelphia exported 76,636 gal. in 1879. The production of whale-oil in the American fisheries (excluding spermaceti) was 1,091,930 gal. in 1879.

Next to America, ranks Scotland, and afterwards Norway. France and Germany have quite retired from the whale-fishery. The Scotch vessels hail from Peterhead, and Dundee. From the former port, 13 obtained 19 whales, 737½ tuns of train-oil, in 1869; in 1879, 7 secured 11 whales, 234 tuns of oil. Dundee, in 1869, despatched 11 vessels, which took 9 whales, 576 tuns of oil; in 1879, 15 captured 55 whales, and had a total of 1746 tuns of oil; in 1874, the figures were 190 whales, 1994 tuns oil. The fishing takes place partly in the European polar sea, partly in the Cumberland Gulf. The Norwegian whalery is almost confined to the Waranger Fjord, where 130 head, chiefly "finners," were taken in 1878. The Danish Greenland fishermen secure only 2 or 3 whales annually. The polar whale is found off the coast here and there between 65° and 70° N. lat. A station still exists in Holsteinborg. The chase lasts from December to March. In summer and autumn, they also meet with the humpback whale, in years when there is little or no drift ice. New Zealand had a whale-fleet of 13 vessels in 1877, hailing chiefly from Otago; the value of their take was 41,740*l.* Tasmania had 12 vessels engaged in 1877, whose catch was valued at 31,605*l.* The exports of whale-oil from Honolulu in 1878 were 7254 gal. to Germany. The Bay of Panama was very productive in whale-oil during 1878, the number of sperm-whales and humpbacks captured considerably exceeding that of previous years. In 1877, the number of barrels (of 30 gal.) of oil obtained was 727; in 1878, it amounted to 2710. The industry is carried on by American vessels from San Francisco and New Bedford, and by Chilian vessels from Valparaiso the latter being owned chiefly by English firms there. From the St. Vincent (W. Indies) whale-fishery, the exports were 610 barrels, 1830*l.*, in 1876; 750 barrels, 2259*l.*, in 1877; 581 barrels 1264*l.*, in 1878; 370 barrels, 315*l.*, in 1879. From Barbados, they were 1108*l.* in 1877, and 1887 in 1878. The value of Norwegian exports has fallen from 913,200 *kroner* (of 1*s.* 1½*d.*) worth of train-oil, and 66,000 *kr.* of whale-blubber, in 1875, to 450,900 *kr.* of train-oil in 1879. The quantity of train-oil in 1879 was 143,065 *hectol.* (of 22 gal.). Denmark, in 1878, exported 193,514 lb. of train-oil to Great Britain. Archangel, in 1878, exported 615 tons of train-oil, value 11,630*l.*, to Germany.

The "Greenland" or "right" whale (*Balæna mysticetus*) inhabits the Arctic Seas of both hemispheres; it usually affords about 125 barrels of blubber, which is converted into the so-called "train-oil." The "polar" whale (*B. glacialis*) is abundant around Greenland, Iceland, and the North Cape; it yields about 90 barrels of blubber. The "southern" or "Cape" whale (*B. antarctica*) is found in the South Seas. The "humpback" whale (*Balænoptera Boops*) inhabits the northern seas; it is less rich in oil than the "right" whale. The "finner" (*Balænoptera Gibbar*), a native of northern seas, is difficult to take, and furnishes a small quantity of oil, but of excellent quality. *Balæna rostrata* is met with on the coasts of Scotland. The thickness of the "blubber," or oleaginous cellular membrane, in a whale varies from 8 to 20 in. It is very coarse in texture, and harder than pork. The oil is drained from it by cutting it into pieces and placing these in racks, through which the oil drips down into casks. It is then heated at 107° (225° F.) to remove the unpleasant odour, and to assist the clarification. It is next pumped over with water, left to cool, and finally barrelled. (For Spermaceti, see p. 1371).

Miscellaneous.—Besides the oils and fats mentioned under the preceding headings, all of which are important commercial articles, there are many others obtained from members of the animal kingdom, some identified, others not yet referable to exact species, which, though not deserving of such prominent notice as the former, still cannot be altogether overlooked. They are as follows:—

Alpaca-tallow, the fat of some species of *Auchenia* (see Hair—Alpaca, p. 1093), is used in pomades in portions of S. America.

Anabas scandens, in the Malay Archipelago, gives a fish oil.

Ant-grease is obtained from white ants or termites on the Gaboon, by boiling them in large vessels, and skimming off the fat which floats; it is used as food. Another yellow or reddish-brown fatty oil is produced by expressing the residue left on distilling ants.

Badger-grease was formerly used in medicine, and is now employed in Austria for carriage-grease; melting-point, 30° (86° F.).

Barbus Chola, in the Malay Archipelago, gives a fish oil.

Bat-grease (Fr., *Graisse de Roussette édule*) is obtained from the "kalong" or (erroneously) "flying-fox," a large bat (*Pteropus edulis*) of New Caledonia, the Moluccas, and the Sundas; it has the properties of lard.

Bear-grease, from N. America, was formerly used in medicine and perfumery.

Beetle-oil, obtained from *Carabus saponarius*, of Senegal, is used as soap.

Cochineal-fat, from the cochineal-insect (*Coccus cacti*), melts at 40° (104° F.).

Cockchafer-oil (Fr., *Huile de Hanneton*), obtained from *Melolontha vulgaris*, is used for lighting, and for the manufacture of carriage-grease, in Hungary.

Conger-eel-oil is obtained from *Muræna Congre* in the N. Atlantic (see p. 1364).

Cooawanoo-oil is procured from the reptile *Caouana divacea* [*Chelonia Cephalo*] in the E. Indies.

Dog-grease is used medicinally, and in the manufacture of glazed gloves, on the Continent; melting-point, 26½° (79⅘° F.).

Duck-grease, from *Anser spp.*, contains 72 per cent. oleine and 28 stearine; melting-point, 25° (77° F.).

Emu-grease, from *Dromaius novæ hollandiæ*, is obtained by boiling the skin in small pieces after removal of the feathers, and is much esteemed by the colonists and natives of Australia as a remedy for sprains and rheumatism.

Frigate-bird-oil is got from the "frigate-bird" (*Tachypetis aquila*) in tropical regions.

Fulmar-oil is derived from the "fulmar petrel" (*Procellaria glacialis*), which bird is found in myriads on the islands of the N. Atlantic, e. g. the Hebrides, Orkneys, Shetlands, Færoes, and Iceland; the oil is abundant, and resembles that from cod-liver. (For Petrel-oil, see p. 1376).

Fur-seal-oil, from *Otaria spp.*, is occasionally imported into London by the Falkland Islands Co.; each animal's blubber furnishes about ½ gal. of excellent oil, adapted to the same purposes as ordinary seal-oil; it is mostly wasted. The value of the exports is included in Penguin-oil (see p. 1376).

Gata-oil, from an unknown fish, is used in the Cape Verdes, and esteemed superior to cod-liver-oil in medicine.

Ghee, or clarified butter, chiefly made from buffalo-milk, is universally employed in domestic cooking in India, and is an important article of local trade. Thus the value of the exports from Persia in 1879 were 15,000 rupees from Bushire, 32,000 from Lingah, and 5000 from Bahrein.

Giboia-grease (or oil) is from an undetermined Brazilian animal.

Goose-grease contains 68 per cent. oleine and 32 stearine.

Guacharo-oil is obtained from the so-called "oil-bird," *diablotin* (French Antilles), or "Trinidad goat-sucker" (*Steatornis caripensis*), found in Venezuela, Trinidad, Ecuador, the Peruvian Andes, and New Granada. It is a nocturnal bird, inhabiting deep, dark caverns, and feeding exclusively on oleaginous fruits. The young, soon after being hatched, become a mass of fat, when they are taken in immense numbers by the Venezuelan Indians, about midsummer, by the aid of torches and long poles; their fat is removed, and melted down over fires kindled at the cavern mouth, and the oil is run into earthen pots, and preserved for cooking and lighting purposes; it is pure and limpid, free from unpleasant taste or smell, and keeps sweet for a year.

Guariba-grease (or oil), from an undetermined Brazilian animal, is recommended against rheumatism.

Hippopotamus-grease, when boiled, is very similar to lard, but has always an oily consistence in S. and Central Africa; it has a slight flavour of train-oil, but keeps for many years without becoming rancid.

Hwangkuyn is an oil from an undetermined Chinese fish.

Iguana-grease, from *Iguana tuberculata*, is utilized in S. America.

Lamprey-oil, from *Petromyzon fluviatilis*, is used in Russia.

Ophiocephalus striatus, in the Malay Archipelago, affords a fish oil from its intestines.

Ostrich-grease, from *Struthio Camelus*, is used by the Arabs in food and medicine.

Ounce-grease, from *Felis Uncia*, is employed in Brazil.

Peacock-grease is esteemed in the E. Indies.

Penguin-oil is obtained from the "Patagonian penguin," or *manchot* (*Aptenopodites patagonica*), found in S. America; the bird is so abundant in Patagonia that one vessel has obtained more than 225,000 pints of its oil in 5 weeks; it is imported into London by the Falkland Islands Co., and is employed in leather-dressing. The value of the exports of penguin-oil (including seal) to the United Kingdom, were 1312*l.* in 1878, and 1200*l.* in 1879.

Petrel-oil is procured from two species of petrel, *Procellaria obscura* and *P. brevicauda*, the former in New Zealand, the latter in Tasmania, by pressing the bodies of the birds, who are allowed to escape alive, to accumulate a fresh supply; it burns very well in lamps, and is also employed against rheumatism. (For Fulmar-oil, see p. 1375).

Pheasant-grease, melts at 43° (109° F.).

Pigeon-grease (or oil), from *Columba migratina*, is used by the natives of N. America as a substitute for butter.

Piraracu-oil, from *Vastris gigas*, and perhaps other species, is employed in Brazil, Guiana, &c., against rheumatism.

Raposa-grease, from a species of fox, is used medicinally in Brazil.

Ray-oils are very extensively procured from the livers of *Raja clavata*, *R. pastinaca*, and other species indigenous to Indian seas, and possess qualities like those of cod-liver-oil (see p. 1364).

Salmon-oil, from a species of *Salmo* found in China, sometimes enters into the composition of "Indian ink."

Sandre-oil is obtained in Russia from the fat surrounding the intestines of *Leucoperca Sandre*, and is used like sturgeon-oil (see below).

Saw-fish-oils are procured from several species of *Pristis:* the liver of the sword- or comb-fish of Guiana (*P. pectinatus*) affords 15–20 gal. of oil, used for lighting and anointing; another species in India contributes very largely to the mixture of oils known as "Malabar oil" (see p. 1367).

Sea-wolf-oil is obtained from *Anarrhicus lupus* in the North Sea.

Silkworm-oil is extracted from the chrysalides of the silkworm, by pressure, by treatment with bisulphide of carbon, or by exhausting with alcohol and washing the extract with hot water; it is brownish-green, lighter than water, neutral, remains liquid at 0° (32° F.), is easily soluble in alcohol and ether, is readily saponifiable, and possesses an extremely disagreeable odour. The yield is 15 lb. of oil from 165 lb. of cocoons; the oil burns well in lamps.

Sturgeon-oil is prepared in Russia from the fat surrounding the intestines of the sturgeon (*Accipenser Sturio*), by washing and melting in the fresh state in steam-boilers; it is chiefly used for adding to the barrels of caviare, when the spawn itself is not sufficiently fat. It is also consumed as food. The common grades for industrial purposes are liberated by putrefaction, and amount to 100,000 *poods* (of 36 lb.) yearly.

Tapir-grease, or *Anta-oil*, from *Tapirus suillus*, is used medicinally in Brazil.

Tassoc-oil, obtained from a species of *Silurus*, is an important object of commerce in Cochin China and Siam, and is remarkable for the quantity of stearine it contains. Another species, *S. glanis*, is utilized in E. Europe.

Turkey-grease melts at 45° (113° F.).

Turtle-butter (or oil) is extracted from the eggs and fat of various species of turtle in Brazil and the S. Pacific Islands, and is used in food and medicine, and for lighting. The production in the

Orinoco, Amazon, and Negro rivers is estimated at over 10,000 jars annually. In the S. Pacific, a good-sized turtle will yield 10 gal. of oil.

Yusan is an oil from an undetermined Chinese fish.

A fat obtained from the *larvæ* of an insect living on the "Tucum palm" (*Astrocaryum vulgare*) is used medicinally in Brazil.

British India exported 429,830 gal. of animal oils in 1877, and 1374 gal. in 1879.

VEGETABLE OILS AND FATS [A. *FATTY OR FIXED*].

Almond-oil (FR. *Huile d'Amandes*).—The almond (see Fruit—Almonds, p. 1022) yields two oils: an essential or volatile oil, described in a separate section (see p. 1416); and a fixed or fatty oil, now to be discussed. This latter is afforded by both sweet and bitter varieties, to the extent of 55–60 per cent. For its extraction, the fruit is chosen recently gathered, but not too fresh. The sweet almonds are crushed unpeeled, the bitter are peeled, and deprived of their essential oil. They are shaken up in a bag, and crushed to paste; the latter is put into bags, and pressed. Perfumers, in order to obtain whiter cakes and a superior "paste," plunge them into boiling water, to separate the skins, but this method of proceeding is apt to provoke the rancidity of the oil, and thus diminish its value. Bitter almonds are generally preferred to sweet, as being cheaper, and leaving a useful cake for perfumers. The most esteemed oil is obtained from the almonds of Majorca. The manufacture is carried on principally in Spain, Italy, and S. France. The yield of oil on an industrial scale is said to be 1 lb. 6 oz. by cold expression, and an additional 12 oz. by hot expression, from 5½ lb. of almonds. The oil has a clear yellow colour, and agreeable flavour; it is without odour, and very fluid; its sp. gr. is 0·917–0·920 at 15° (59° F.); it thickens and deposits stearine at − 10° (14° F.), assumes a butter-like consistence at − 20° (− 4° F.), and solidifies completely at − 25° (− 13° F.); it contains 24 per cent. of stearine, and 76 of oleine; it dissolves readily in ether, and in alcohol (25 parts cold, 6 hot). It is employed chiefly by perfumers, but also in medicine. It is frequently adulterated up to 50 per cent. with gingelly-oil, poppy-oil, mustard-oil, and peach-kernel-oil.

American Nutmeg-oil (FR., *Suif de Virola*).—The "American nutmeg" called *Virola sebifera* [*Myristica sebifera*], known as *jejomadon* to the Creoles, and as *malagueto de montana* in Panama, is common in the forests of Guiana and N. Brazil, and extends as far as Panama. The seeds are there bruised, and macerated in boiling water, when a fatty substance separates from them, floats on the water, and solidifies by cooling. This solid fat is transported to Europe in the form of bricks, and has been received in considerable quantities. The yield from the seeds is stated at 26 per cent. The fat is completely soluble in alcohol, ether, and potash ley; its fusing-point is 44° (111° F.); it forms a hard soap, and is admirably adapted for making candles, which burn with a pleasant aromatic odour.

Argan-oil (FR., *Huile d'Argan*).—The seed-kernels of the argan tree (*Argania Sideroxylon* [*Elæodendron Argan*, *Sideroxylon spinosum*]) afford a valuable fatty oil. The tree is found native only in the sub-littoral zone of S.-W. Morocco, where it is common between the rivers Tensift and Sous. A few scattered specimens are said to occur north of the Tensift, and the tree seems to be not infrequent in the hilly district between the Sous and the Oued Noun. Thus its area comprises a total length of about 200 miles, and a breadth extending from near the coast to a distance of 30–40 miles inland. At different times, the seed has been procured and distributed to various colonies, but its slow growth has led to disappointment. At Saharunpore, it did not survive, though probably well suited to N.-W. India. A tree in the Hobart Town Gardens has been fruiting for some years. In Morocco, the tree flowers in the middle of June, and the fruit remains on the tree during the greater part of the year. The young fruit sets in the end of July or beginning of August, and grows slowly till the rainy season commences, towards the end of September. It then enlarges rapidly, and attains its full size during that season, so that, by the middle or end of March, it is ripe enough to be gathered for economic uses. The prominent feature of the tree is the hardihood with which it withstands drought. The harvesting of the seed-kernels and extraction of the oil are performed in the following manner: In the end of March, camels, goats, sheep and cows are driven into the argan woods, when the fruits are shaken down from the trees. The green fleshy pericarp is greedily eaten by these animals, who afterwards reject the seed-kernels. The latter are collected by the peasants, and taken home. The hard bony shells are cracked between stones, and the inner white kernels are carefully extracted. These are roasted on plates of iron or pottery, and stirred constantly meanwhile, until they have a brown colour all over, without being charred on the outside. When the kernels have cooled, they are ground into a thick meal; this is placed in a vessel, moistened occasionally with warm water, and stirred and kneaded with the hand unceasingly, until the mass becomes so hard that it can no longer be kneaded. The harder the mass becomes, the more perfectly is the oil liberated. Finally, cold water is sprinkled over it, to expel the last traces of oil. During the operation, the oil escapes at the sides, and is poured into a clean receptacle at intervals. The main points needing attention are that the kneading shall be thorough, and that the hot water used shall not exceed what is actually necessary. The residual cake is an excellent cattle-food. The oil, when it has settled, has a clear light-brown colour, and a rancid odour and flavour. It is an important domestic oil among the Moors, being used as a substitute for olive-oil. The annual production is estimated at 1000 cwt. for the whole region. It is said that none whatever is exported.

Assai-oil.—A fatty oil is extracted by decoction from the fruit of *Euterpe oleracea* [*edulis*], the *assai* palm, found abundantly in Pará, growing in swampy places, especially on the banks of rivers within the tidal limits. The oil is of greenish colour, and slightly bitter flavour, and is used for illuminating.

Bean-oil.—The seeds of the Chinese oil-bean, the *sooja* or *miso* of the Japanese (*Glycine Soja* [*Soja hispida*]), afford 17–18 per cent. of a fatty oil. The plant is shrubby, attaining a height of 3–4 ft., and resembling the common dwarf kidney or French bean. The seeds are somewhat smaller than French beans, and vary in colour, from white to yellow and green. The plant is chiefly cultivated in the north of China, especially in the province of Shantung. The Chinese usually obtain 17 per cent. of oil from the seeds by simple pressure. The oil bears a general analogy to the ordinary edible oils of commerce, possessing an agreeable flavour and odour. It is useful for burning; exposed to a low temperature, it becomes pasty, and oxidizes rapidly on exposure to the air. As a drying-oil, it might replace linseed-oil for some purposes. As an illuminator, it is being rapidly replaced by American petroleum, but is still extensively used for food. The oil, the cake left after expression of the oil, and the beans themselves, are important articles of Chinese commerce. The exports from Chefoo in 1878 were 2468½ *piculs* (of 133⅓ lb.) of bean-oil, 994,188 of bean-cake, and 160,549⅓ of beans; in 1870, the exports of the oil from this port were 44,530 *piculs*; in 1877, only 327 *piculs*; and in 1879, 1491 *piculs*. The exports of bean-oil from Newchwang were 4947 *piculs* in 1877, 3287¼ in 1878, and 11,630 in 1879; of beans, in the same years, 1,439,062, 2,156,064, and 1,835,444 *piculs* respectively; and of bean-cake, 792,166, 1,924,968, and 1,800,523 *piculs*. Chinkiang exported 69,090 *piculs* of beans in 1877, and 43,784 in 1879. Hankow imported 21,077¾ *piculs* of native bean-oil, value 15,624*l.*, in 1879. Kiukiang, in 1879, imported 17,675 *piculs*. Shanghai, in 1879, imported 282¼ *piculs* from native ports, and exported 33,940 *piculs* (besides 372 re-exports) to native ports. Wuhu imports quantities of the oil from Hohan, viâ Hankow, also from Hochow, Luchowfu, and some other places north of the river; the figures were, 659½ *piculs* in 1877, 13,574¼ in 1878, and 5284 in 1879. The cake is used for human and cattle food, and as manure. (See also Spices—Soy.) The plant is cultivated for its beans in many parts of India and the Archipelago; and has been successfully introduced into Austro-Hungary and N. Germany.

Beech-oil (Fr., *Huile de Faine*).—The fruit or "mast" of the common beech (see Timber) is valued for its oil in some parts of the Continent, notably France, and was so in England also in Queen Anne's reign. The forest of Compiègne is the chief locality for the production of the oil, which there forms an important industry, a vigorous tree being estimated to yield in good years not less than 22 gal. of oil. When the mast is ripe, at the beginning of autumn, it is shaken down upon cloths spread beneath, and sorted; the soundest fruits are placed to dry in the shade, crushed between rollers or in a mill, and sifted or fanned to remove the shells. Thus treated, the dried kernels are put into troughs, and stamped to a paste; this latter is enclosed in bags, and subjected to pressure; the escaping oil is poured into capacious vessels, and left to deposit the mucilaginous matters extracted by the pressure, after which, it is ready for commerce. This process is the best, not only as regards the oil produced, but also as affording a good cattle-food in the refuse cakes. Unfortunately, the shelling of the kernels is often omitted, when the shells retain some of the oil, and only release it on boiling in water, by which its character is impaired. Occasionally the nuts are hand-shelled singly, and treated with such care, that the cake left after expression of the oil contains sufficient amylaceous matter to be used as a kind of bread. The yield of oil is about 12–15 per cent. (20–25 per cent. by carbon bisulphide), or 1 gal. of oil from 1 bush. of mast. The newly-extracted oil has an acrid flavour, which disappears in time, or may be removed by washing with cold water. The oil has a clear-yellow colour, a peculiar odour, and a faint flavour; freshly-drawn, it is thick and cloudy; after sufficient rest, it is limpid, but slightly viscous. Its sp. gr. is 0·922 at 15° (59° F.); it becomes turbid at – 10° (14° F.), and congeals at –18° (0° F.) to a yellowish white mass; and keeps long without becoming rancid. It is sometimes used instead of butter for cooking in E. France, but is more commonly employed to adulterate olive-oil. It serves for illuminating; and forms with soda a dirty-grey, hard soap, but which always remains greasy.

Ben [Oil of] (Fr., *Huile de Ben, de Behen*).—Oil of ben is extracted from the so-called "ben-nuts," the seeds of one or more species of *Moringa*. The principal are *M. pterygosperma* [*M. oleifera*, *Guilandina Moringa*, *Hyperanthera Moringa*] and *M. aptera*. The former is a native of the E. Indies; the latter is said to be indigenous to Egypt and Arabia, and has long been naturalized in the

W. Indies. They are common objects of cultivation throughout India and Burma, in the N.-W. Himálaya up to 1500 ft., in Egypt, and in the W. Indies. The Indian species occurs wild in the lower Himálaya and Siwalik tract, from the Chenab to the Sardab, also in the Oudh forests. The seeds of both species are rich in fatty oil, which is extracted by simple pressure; it seems to be less availed of in India than in the other habitats of the trees. The Indian oil has a sp. gr. of 0·912–0·915 at 15½° (60° F.); it is fluid at 25° (77° F.), thick at 15° (59° F.), and becomes solid at lower temperatures; it is almost devoid of odour and flavour, has a pale-yellowish colour, saponifies slowly, and does not turn rancid. It consists essentially of oleine, margarine, and stearine. After separation of the solidifiable portion by cooling, it is highly esteemed by watchmakers as a lubricant, for which purpose it has been extensively imported. Locally, it is employed in medicine; also by perfumers, as it possesses great power of absorbing and retaining even the most fugitive odours. It is very commonly adulterated with virgin olive-oil. In the W. Indies, it is said to be used as a salad-oil.

Bicuhiba-wax (Fr., *Cire de Bicuiba*).—The fruit of the *bicuhiba* or *ucuhuba* of Brazil (*Myristica Bicuhiba*), affords a concrete oil, of yellowish-white colour, soluble in boiling alcohol, and melting at 35° (95° F.), which is locally employed in candle-making, and as a remedy for asthma, rheumatism, and tumours.

Bladder-nut-oil.—The kernel of the fruits ("bladder-nuts") of *Staphylea pinnata* are expressed in some parts of Central and E. Europe for the bland oil which they yield.

Boma-nut-oil.—The Boma-nut (see Nuts, p. 1351) which is not a species of *Vitex* as there supposed, but has been called *Pycnocoma macrophylla*, furnishes an abundance of sweet bland oil, much used in cooking by the natives of central Africa.

Butter-nut- or Souari-oil.—The fruits of *Caryocar nuciferum* and *C. tomentosum*, lofty trees inhabiting the forests of tropical S. America, notably the banks of the Essequibo and Berbice rivers, afford edible oils.

Cacao-butter or Oil of Theobroma (Fr., *Beurre de Cacao*; Ger., *Cacaobutter, Cacaotalg*).—A valuable concrete fatty oil is derived from the seeds or beans of the cocoa- or chocolate-tree, principally *Theobroma Cacao* (see Cocoa, p. 684). This oil is procured almost exclusively from the chocolate-makers, who express it in the process of preparing the cocoa-nibs for the production of the article in various edible forms. The nibs are ground in heated mills, by which the oil is disengaged, and the mass becomes a soft paste; this is placed in canvas bags, and subjected to pressure under the influence of steam-heat. The oil then escapes in a perfectly liquid condition, and is collected in oblong tins. When necessary, it is decolorized by filtration through ivory-black, i.e. very fine animal charcoal. The yield of oil is from 30 to 45–50 per cent. of the weight of nibs. On cooling to ordinary temperatures, the oil becomes a light-yellowish, opaque, dry substance, unctuous to the touch, but brittle enough to break into fragments when struck, and showing a dull waxy fracture; it has a chocolate-like odour, and a pleasant bland flavour; its sp. gr. is 0·945–0·952; its fusing-point is 20°–30° (68°–86° F.); it is soluble in ether and spirit of turpentine; it dissolves also in 20 parts boiling alcohol, but only 1 per cent. remains in solution after cooling; it dissolves slowly in double its weight of benzol at 10° (50° F.), but partially separates by keeping; it may be kept for a long time (even several years) without turning rancid; it consists chiefly of stearine, and a little palmitine and oleine. It is extensively used in pharmacy, especially on the Continent. It is often adulterated with tallow, wax, &c., but its peculiar characters facilitate their detection.

Calaba- or Galba-oil.—The tree affording *calaba*-nuts (*Calophyllum Calaba*) flourishes most abundantly in Brazil and the W. Indies. Its seeds yield an excellent illuminating-oil.

Carmaru-oil.—The fruit-seeds of the eboe-tree (*Dipteryx eböensis*), and perhaps also those of the better known species, *D. odorata* (see Perfumes—Tonquin-beans), contain a large quantity of a clear, yellow, fixed oil. The trees flourish throughout Brazil, Guiana, and the Mosquito country (now the E. part of Nicaragua), but it is particularly in the last-named district that the oil is extracted and utilized by the natives. Its chief applications are for anointing the hair, and for curing ulceration of the throat.

Cashew-nut-oil, and Cardole.—The cashew-nut (see Nuts, p. 1352) affords two kinds of oil. The kernels, which have occasionally been imported into England from India as "cassia nuts," yield a light-yellow, bland, nutritious oil, of the finest quality, in every respect equal to almond-oil, and considered superior to olive-oil. It is very seldom expressed in India, as the entire kernels are so extensively eaten. A second oil, called *cardole*, or "cashew-apple-oil," is obtained from the pericarps or shells of the nuts; it is black and acrid, and is a powerful vesicating agent. It is employed in surgery as a caustic, and is frequently applied to timber which is exposed to the attacks of white ants. The yield of oil from the kernels amounts to 40½ per cent. commercially, and from the pericarp 29½.

Castanha-oil (Fr. *Huile de Juvias, de Châtaignes, de Castanheiro.*)—The castanha or Brazil-nut (see Nuts, p. 1351) is very rich in oil; each fruit contains some 20 nuts, and each lb. of nuts gives

10 oz. of oil. This is extracted by roasting the nuts, and pounding, pressing and straining the kernels. A superior product is obtained from the unroasted nuts. It is bland, pleasant, and of clear-yellow colour, and, in composition, differs but little from fixed almond-oil, which it resembles in its tendency to become rancid when kept. This last property renders it applicable only to illuminating, perfumery, and soap-making, for which it is well adapted. It is used for culinary purposes when fresh. It could be furnished in considerable quantities.

Castor-oil (Fr., *Huile de Castor, de Ricin, de Palma-Christi*; Ger., *Ricinussamenöl*).—The castor-oil-plant, or *Palma-Christi*, as it is often called, belongs to the genus *Ricinus*, of which some 16 forms are distinguished, but all usually considered mere varieties of *R. communis*. The variety known as *R. spectabilis* is said to give 22 per cent. more oil. The plant is indigenous to India, whence it has been distributed by cultivation throughout all the tropics, and in many temperate countries. It flourishes in India, China, Java; the Azores, and the W. African coast; the Mediterranean region (Algeria, Egypt, Greece, Spain, Crete, Sicily, and the Riviera); France, Germany, and England; Brazil, Spanish America, and the Portuguese colonies; the United States and the W. Indies; and in good summers, ripens its seed as far north as Christiania, in Norway. In the most favourable situations, it attains a height of 40 ft.; in the S. States of America, often 20–25 ft.; in the Mediterranean region, 10–15 ft.; in India, 8–10 ft.; in N. Europe, 4–5 ft.

The plant is probably most extensively grown in India, not only for the oil yielded by its seeds, but also on account of its leaves forming the food of some kinds of silkworm. Its cultivation is carried on in most parts of India. The whole of the N.-W. Provinces produce castor-oil, but inferior in quality to that obtained from the coast-grown seed of Coconada and that of Colcong. The plant might be raised much more extensively in Oudh. In Cuttack, it occupies much newly-cleared land, in the jungles of the Tributary States and Sumbulpore. Madras Presidency is reckoned to have 67,000 acres under this crop, chiefly in Coimbatore. Scarcely any cultivation is required, and the plant is frequently grown as a border for more valuable or delicate crops, especially as all insects are said to avoid it. It prefers a sandy loam, and will not thrive on clay. It attains full perfection as a hedge-plant, and flourishes well on newly-cleared jungle-land. Two kinds of the plant are distinguished by Indian native cultivators, a large-seeded and a small-seeded. Both are raised from seed, which is sown twice annually, in November and May. The natives sow and uproot the plant every year, though it grows and yields abundantly in the second and third years in open spaces. When growing it alone, they almost always sow too thickly, and thus prevent the proper development of the plant. The operation of gathering the seeds is tedious. The two kinds are kept distinct, the oil obtained from the small-seeded sort being esteemed much superior. Separate methods of extraction are also adopted.

The seeds of the small-seeded variety are treated as follows. Having been sifted clear of all dirt and foreign matters, while still fresh, they are slightly crushed between two rolls, then freed by hand from husks and coloured grains, enclosed in clean gunny-sacks, and lightly pressed in oblong moulds to form "bricks" of uniform shape and density. These bricks are placed alternately with sheet-iron plates in an ordinary press, and the escaping oil is caught in clean tinned pans. To each 1 gal. of oil, is added 1 pint of water, and the whole is boiled till the water has evaporated; the result of this is that the mucilage subsides, and encrusts the bottom of the pan, while the albumen solidifies, and forms a white layer between the oil and the water. The utmost care is necessary to remove the pan from the fire the moment the evaporation of the water is complete, as known by the cessation of bubbling; if allowed to remain longer, the temperature, hitherto that of boiling water, 100° (212° F.), suddenly rises to that of boiling oil, 315½° (600° F.), thereby deepening the colour and developing an empyreumatic odour and flavour. The oil is filtered through blanketing or similar fabric, and put into canisters for export. It is known as "cold-drawn" oil, and is usually of a light-straw to greenish colour. The cleaned seeds yield 47–50 per cent. of oil by this method, fit for the European market. Experiments with Calcutta seed resulted in a product of 324 lb. 1st class oil, 87½ lb. 2nds, and 76½ lb. 3rds, or a total of 488 lb. of oil from 1400 lb. of seed (980 lb. of kernels); 1400 lb. of Madras seed gave 318 lb. 1sts, 88 lb. 2nds, and 74 lb. 3rds, total 480 lb. The cost of the Madras oil, including the seed at R. 3·3 per bag of 164 lb., husking and selecting the kernels, crushing, moulding, pressing, boiling, filtering, overseers' pay, godown rent, 300 empty quart bottles, corks, cleaning, packing-charges, and sundries, was 76 *rupees* 1 *anna*, or an average of 4·06 *annas* per qt. of 1st, 2nd, and 3rd oil, or 4*d*. a lb. A second Indian method of exhausting this kind of seed is by hot-water extraction. The seeds are boiled in water for 2 hours, sun-dried for 3 days, shelled, pounded, and boiled in fresh water till the whole of the oil has risen to the surface. The yield is 1 qt. of oil from 3⅛ lb. of seed. It is straw-coloured, free from unpleasant odour and flavour, and is commonly used by native medical practitioners.

The oil of the large-seeded variety is occasionally extracted by the cold process, but most commonly by a combination of roasting and boiling. The seeds are first partially roasted over a charcoal fire, both to coagulate the albumen and liquefy the oil; they are then pounded, and boiled in water till the oil rises to the surface. The yield is about 33 per cent. of a very impure oil having a deep-red colour, and an empyreumatic odour, which is often very offensive during its combustion in lamps; it is thick and viscid, and soon grows rancid. It is produced only for home consumption, forming the common "lamp-oil" of the bazars, and being very extensively used for dressing articles of leather.

Most of the Indian oil is extracted in and exported from Calcutta, the crushed seed being sent up from Madras for the purpose—an inexplicable proceeding. The exports from Calcutta in 1870–1 were 654,917 gal., of which, 214,959 gal. were for the United Kingdom; in 1877–8, the total Indian export had grown to the very large figure of 1,411,216 gal. It is sent to the United Kingdom, Mauritius, the Straits Settlements, Ceylon, and Australia, chiefly, it would seem, for lubricating purposes, much of it being obtained from the large-seeded kind, and extracted by the roasting and boiling process.

The manufacture of castor-oil is actively carried on in the United States, especially at St. Louis, the seeds being largely produced in S. Illinois. In 1875, Kansas had 24,145 acres under this crop, producing 361,386 bush. of seed. Other states participate in the industry. The land is prepared as for other crops, and the seeds are planted much the same as maize, except that only one seed is put into each hill, and that every fourth row is missed to afford space for the harvesting. Ripening commences in August; the yield varies from 15 to 25 bush. an acre, 20 being considered fair. The oil is generally extracted in the following manner. The seeds, having been thoroughly cleansed from the dust and particles of the pod with which they are always contaminated, are placed in an iron tank, and heated to such a degree as will liquefy the oil without any risk of scorching. They are then pressed, the oil escaping being known as "1st quality." The pressed seed is heaped up and left for a day; on the following day, it is again heated and pressed, and gives a "2nd quality" oil. The yield from 1 bush. of seed is 12 lb. of 1st quality, and 4 lb. of 2nd quality oil; sometimes a 3rd expression is made, giving 1–3 lb. of a very much coloured oil. Occasionally too, the cake from the 2nd pressing is treated with bisulphide of carbon, which extracts a small additional quantity of thick, dark, common oil. All qualities need purifying and clarifying. This is usually effected by boiling first with a large quantity of water, and skimming off the impurities as they rise, while the mucilage and starch are dissolved, and the albumen is coagulated. The clear oil is removed and boiled with a very little water, which clarifies it, and drives off volatile acid matters. The chief point to be noticed is to expose the oil as little as possible to the air, or it quickly becomes rancid. The 1st quality oil is used medicinally, the 2nd for burning, lubricating, leather-dressing, &c. In America, the cake is frequently used as fuel.

Italian castor-oil has lately attracted some notice. It is principally expressed from the seed of plants grown in the province of Verona, especially the district of Legnago, in N. Italy; the produce is now 400,000 *kilo.* of seed yearly, but all Italian-pressed oil is not from Italian-grown seed, as Genoa imports considerable quantities of the seed from India. Two varieties are cultivated in Italy, the black-seeded Egyptian and the red-seeded American; the former yields the lesser percentage, but of a paler colour. The seeds are very carefully peeled, and after crushing, are placed in hydraulic presses, standing in a room which is heated to 21° (70° F.) in winter. The exudation of the oil is promoted by warming the press-plates to 32°–38° (90°–100° F.). The yield of oil is about 40 per cent. on the peeled seeds.

The castor-oil-plant grows as a weed in the Bahamas, but the little oil which is extracted by boiling is never met with in commerce. A supply of the best Indian seed has been sent to these islands, and is found to afford three times as much oil as the native plant, besides being quite as readily cultivated. Hopes are entertained that the colony will soon be an important producer of the oil. The plant has been introduced into Brazil from India, and attains an immense size; in 1879, an attempt was made to export castor-oil direct from Maceio to Europe, and probably large quantities will eventually be sent, as it is most extensively produced in the province of Alagoas, and locally used in lamps; the value of the shipments coastwise from Maceio rose from 16*l.* in 1877 to 117*l.* in 1879. In Angola (W. Africa), the dry sandy beds of the rivers in the hot season are often completely covered with a magnificent growth of the castor-oil plant. Among other countries, China may be mentioned as yielding considerable quantities of castor-oil; the exports from Newchwang were 581 *piculs* (of 133⅓ lb.) in 1877, and 1664 in 1878; Shanghai exported 555 *piculs* to other Chinese ports in 1878, and 3 *piculs* to Chinese ports, and 76 *piculs* to foreign countries, in 1879. In France, the fresh seeds are bruised and pressed in the cold, and the albumen and mucilage are separated by long standing and filtering; the product is 33 per cent. of the seeds, but is much weaker (less purging) than that obtained from the tropics. This remark applies also to the Italian oil. Rarely, the bruised seed is macerated in cold alcohol, 1 lb. of seed then giving 6 oz. of oil. Algeria and Egypt are large producers.

As to the claims of the plant upon cultivators of oil crops, Dareste estimated the yield to be 1800 *kilo.* (of 2·2 lb.) per *hectare* (of 2½ acres), while a similar area of oil-palms in the tropics gave only 900 *kilo.*, and of olives in S. Europe 600 *kilo.*; the seed was calculated to afford 52 per cent. of oil.

Castor-oil has a sp. gr. of 0·969 at 12° (53½° F.), 0·957 at 25° (77° F.), and 0·908 at 94°

(201¼° F.); it has usually a pale-yellow colour, viscid consistence, and slight mawkish odour and flavour, which are much intensified when it becomes rancid; at—15° (5° F.), it commences to congeal, but does not completely solidify above—18° (0° F.), when it dries up, forming a transparent varnish-like film in three layers; its boiling-point is 265° (509° F.), when it begins to distil, and affords various products; it mixes in all proportions with glacial acetic acid and absolute alcohol, and is even soluble in 4 parts alcohol of 0·838–0·850 at 15° (59° F.), and forms a clear mixture with equal weights of the same at 25° (77° F.); it is said also to render other oils mixed with it soluble in alcohol. It saponifies readily, yielding several fatty acids, the chief of which is ricinoleic ($C_{18}H_{34}O_3$), peculiar to this oil, and another appears to be palmitic. Its drastic principle and optical properties still await investigation. Some of its uses have already been alluded to. For medicinal use, as a purgative, the cold-drawn oil is the only kind fit for human subjects; but the oil obtained by roasting and boiling, or that extracted by alcohol, is preferred by veterinary surgeons, as containing much more of the drastic principle, and being therefore more powerful. The common kinds are largely used by leather-dressers, principally, perhaps, for morocco leather, but with equal success on all descriptions; moreover, it repels rats and other vermin, and does not interfere with subsequent polishing. As a lubricant, it is in extensive use in Europe and America; and as a lamp-oil, in India, Brazil, &c. Chiefly three sorts appear in the London market—that expressed here from imported (essentially Egyptian) seed, E. Indian expressed, and American expressed. The oil is imported in tins, barrels, hogsheads, and duppers. It is often adulterated with poppy-seed-oil and croton-oil. (See Drugs, p. 798).

Chaulmugra- and Lukrabo- [Lucrabau-] oils.—The valuable medicinal oils known as *chaulmugra* in India, as *lukrabo* in Siam, and as *ta-fung-tsze* in China, are obtained from the seeds of one or more species of *Gynocardia*; the Indian species is called *G. odorata* (*Chaulmugra*, *Hydnocarpus odorata*), while the other kinds are not yet specifically determined, though some botanists consider them identical. *G. odorata* grows in the forests of the Malayan peninsula and E. India (Tenasserim, Rangoon, Chittagong) as far north as Assam, and thence westwards along the base of the Himálayas, and on the Khasia Hills. It is a large tree, bearing fruits somewhat resembling an orange, in the pulp of which are imbedded the seeds whence the oil is extracted. The fragrant flowers appear in April–May, and the fruits ripen in December. The latter are then collected, dried, and sent to Calcutta; the outer integument is removed, and the kernels alone are treated for their oil, during a period extending to the end of February. The freshest seeds, gathered in December, afford the best yield of oil, which (by expression) amounts to about 10 per cent. Both cold and hot expression are adopted, the oil obtained by the former having superior keeping qualities. At ordinary European temperatures, the oil is a granular solid, resembling beef-dripping in colour and appearance, but of firmer consistence. In the Indian climate, it is more liquid, of a pale-sherry colour, and sp. gr. 0·900; a granular, white, fatty deposit is thrown down by keeping. The melting-point as ascertained in England is 42° (107½° F.), when the sp. gr. is 0·930. It has an acid reaction a slight persistent acrid flavour, and a faint scammony-like odour. A peculiar feature of the expressed oil is its (hitherto) indestructible green colour. The kernels treated with ether afford over 50 per cent. of fatty oil, which is almost colourless, or brownish when the seeds are not fresh. The expressed oil concretes at 17° (62½° F.); that extracted by ether or bisulphide of carbon requires a lower temperature. The chief constituents of the oil are about 63 per cent. of palmitic acid and 11½ per cent. of gynocardic acid in combination with glyceryl as fats; the latter acid is the seat of the colour and flavour, and probably also of the medicinal activity (see Drugs, p. 799) of the oil. The chaulmugra-oil met with in the Indian bazars is universally adulterated, and quite unreliable, as the detection of its impurities is practically impossible. The pure oil has been largely introduced into medical practice in this country through T. Christy and Co., Fenchurch St., and Corbyn, Stacey & Co., High Holborn. Of the closely allied Siamese drug, it may be mentioned that 48 *piculs* (of 133⅓ lb.) of lukrabo-seeds were exported from Bangkok to China in 1871. In 1879, Hankow imported 742 *piculs* of the seed, value 490*l.*; and Shanghai imported 552¾ *piculs* from foreign countries, and 924⅓ from Hong Kong and Chinese ports, 410¼ being retained for local consumption.

Chequito.—This name is applied by the Kaffirs to a fatty substance yielded by the fruit of the "butter-tree" (*Combretum butyraceum*) of S.-E. Africa. It is largely used by them in admixture with their food, and is exported. It consists of about 25 per cent. oleine and 75 margarine, and possesses an aromatic flavour.

Cherry-oil.—The "stones" of the American red cherry (*Prunus serotina*) have for several years past appeared in the market in such abundance and at such a price as to induce manufacturers to extract their oil. For this purpose, the whole "stones," kernels and shells together, are ground to fine powder, which is carefully dried, and subjected to hydraulic pressure of about 2000 lb. a sq. in. The yield is about 5 per cent. of an oil having a slight (but not injurious) odour of bitter almonds, a sweet and agreeable flavour, and a dark-green colour which cannot be removed by either cold or hot water or alcohol; its sp. gr. is 0·906; it solidifies at −9½° (15° F.); its boiling-point is above that of mercury, which is 350° (662° F.), when it takes fire and burns with a yellow flame, leaving a pitch-like residue; at 138° (280° F.), it emits vapours, which are not disagreeable till 315° (600° F.) is reached; it is insoluble in alcohol, but freely soluble in ether, chloroform, oil of turpentine, olive-oil, and benzol.

Chironji-oil.—The fruit-kernels of *Buchanania latifolia*, a common forest-tree in Coromandel, Malabar, and Mysore, yield 50 per cent. of a pure, pale-straw-coloured, limpid, sweet, wholesome, edible oil, seldom found in the market, as the kernel is an esteemed dessert-fruit.

Cocculus indicus (see Drugs, p. 808).—The seeds contain about 50 per cent. of fatty oil, principally composed of stearine, which is extracted by the natives of India, and used for industrial purposes, but seems to be quite unknown in commerce.

Coco-nut- and Copra-oils (Fr., *Huile de Coco*, *Beurre de Coco*; Ger., *Cocosnussöl*, *Cocostalg*, *Cocosbutter*).—As indicated by its name, this oil is obtained from the fruit of the coco-nut-palm. The cultivation and distribution of this valuable tree have already been fully discussed elsewhere (see Nuts, p. 1353); the present remarks will be confined to the oil.

The albuminous pulp dried at ordinary temperatures (called "copra" or "copperah") contains 54·3 per cent. of oil, and dried at 100° (212° F.), 66 per cent. For preparing copra, only ripe nuts should be collected, and they should not be broken till 4–6 weeks after gathering; the copra then dries more quickly, does not become mouldy, and affords a greater yield of oil.

An Indian method of extracting this oil, when it is required to be colourless for perfumery manufacture, is as follows. The kernel is plunged into water, and boiled for a few minutes, then grated, and placed in a press; the emulsion thus obtained is boiled until the oil rises to the surface. This process is not cheap enough for ordinary commercial oils, and recourse is had to rude forms of oil-mill, worked by oxen, and treating about 130 lb. of copra daily, obtaining about 40 qt. of oil. Another plan is to divide the kernel into pieces, and dry them on shelves over charcoal fires; after 2–3 days, they are put into the press. By this method, 100 nuts carefully dried are estimated to yield by pressure 10–13 *edangalies* (of 92 cub. in.) of oil, or 40 nuts to a gallon; inferior nuts will not give more than 3–9 *edangalies*; those from trees on salt marshes afford the least oil.

In 1870–1, Bengal exported 7818 gal., and Bombay, 61,735 gal.; Madras shipped 1,088,887 gal. in 1869–70. The value of the oil exported from Malabar in 1873 was 356,187*l.* The exports of the oil from Ceylon were 278,216 cwt., value 330,689*l.*, in 1872, and 175,423 cwt., 204,661*l.* in 1878. The best comes from the Malabar ports, and locally fetches 20*s.* a ton more than that from Ceylon or the Coromandel Coast; yet in Western commerce, Ceylon oil is considered the best, and commands the highest price, Cochin and other kinds following.

The natives of Matabello (Ke Islands) are almost entirely occupied in making coco-nut-oil, which they sell to the Bugis and Goram traders, who carry it to Banda and Amboyna.

In the vicinity of Borongan, in the Philippines, quantities of coco-nut-oil are produced, and some 12,000 pitchers of it are exported yearly to Manilla; the nuts locally consumed would afford at least another 8000 pitchers. About 1000 nuts are required to yield 1½ pitchers of oil by the rude process here adopted, which is as follows. The kernel is rasped out of the woody shell of the nut on rough boards, and placed in old boats elevated on posts to undergo putrefaction; the oil escapes through the crevices of the boats into vessels placed beneath, and the pulp is finally pressed. The whole operation occupies several months, and yields a dark-brown viscid article, worth only 2¼ dol. in Manilla, where a superior oil fetches 6 dol. Recently a factory has been erected at Borongan for the better preparation of the oil. The grating of the pulp is performed by iron discs with toothed edges, radiating from the ends of iron rods, and bluntly pointed towards the centre of the fruit. These discs are made to rotate by suitable gearing, while the workmen force the inner face of half coco-nuts, held firmly by both hands, and pressed by means of a pad on the chest, against the revolving rasps. The finely shredded nut lies for 12 hours in flat pans, to undergo partial decomposition, and is then gently pressed; the resulting liquor, consisting of ⅓ oil and ⅔ water is caught in tubs, and after standing for 6 hours, the supernatant oil is skimmed off. The latter is next heated in iron pans holding about 20–25 gal., until all the water has evaporated, occupying 2–3 hours. In order to cool the oil rapidly, and prevent its deepening in colour, 2 pailsful of cold oil, freed from water, are poured in, and the fire is quickly withdrawn. The compressed shreds are once more exposed to the air, and then subjected to powerful pressure. After these two operations have been twice repeated, the rasped substance is suspended in sacks between strong vertical boards, and alternately squeezed and shaken up for a considerable time. The refuse finally serves as pig-food. The oil which runs from the sacks is quite free from water, and very clear, and is used for cooling that extracted by the boiling process.

Mauritius exported 271,970 gal. of the oil, valued at 28,007*l.* in 1875, and 253,553 gal., value 37,263*l.*, in 1878. The Seychelles exported 162,475 *velts* (of 1·64 gal.) of oil in 1877, and 174,656½ *velts* in 1878.

Tahiti exported 690 tons of oil in 1868, and 420 tons in 1873. The Friendly Islands shipped 704 tons in 1866. The Fiji Islands exported 600 tons in 1864, and 200 tons in 1870.

Improved methods and machinery for extracting coco-nut-oil will be described in a separate section (see p. 1451). The oil is white, and almost as fluid and limpid as water in tropical climates, but solidifies at 16°–18° (61°–64½° F.), and consequently generally appears in Europe as a solid, opaque, unctuous substance, of the consistence of butter, and fusible at 24°–28° (75°–82° F.). When fresh, its odour and flavour are sweet and agreeable, but it quickly becomes rancid. It dissolves readily in alcohol, and saponifies with facility. Its principal fatty acid is laurostearic, together with oleic, palmitic, myristic, and some of less importance, all combined with glycerine. In Europe, the chief applications of the oil are for candle- and soap-making. It is an excellent illuminator, in both candles and lamps, as it emits no smoke; and it forms a hard and very white soap, more soluble in salt water than any other kind made on a commercial scale. During the last 15 years, its consumption for soap-making in England has been greatly reduced by the competition of palm-kernel-oil, extracted here. In the East, the oil is largely used in cooking and medicine while fresh, and for burning, painting, soap-making, and anointing the body, when rancid.

Colza- or Rape-oil (Fr., *Huile de Colza*; Ger., *Colzaöl, Rapsöl*).—Colza-oil and rape-oil are identical, and are derived from several species or varieties of *Brassica*, chiefly *B. campestris* and *B. Napus* [*Napa oleifera*], the seeds being known as rape-seed or cole-seed. The crop is extensively cultivated on the Continent and in India for the sake of the oleaginous seed. The mode of culture practised in Normandy is as follows. The seed is sown broadcast in July, preferably during wet weather, on well-manured land, forming the seed-bed of the future plants. When it is intended to transplant the young plants, the sowing is effected as with turnip- or cabbage-seed. In September–November, the young plants are removed from the seed-bed to a field richly manured with farm-yard dung, and which has just previously grown a crop of wheat. The plants are set out at distances of 18 in. in rows 2 ft. apart; in extra good soil, the crop will be heavier, and more equally ripened, by wider planting. One furrow is generally left between each two rows. The plants quickly recover, and remain thus till February, when the ground is pulverized with a horse-hoe after the frosts. At this season, manuring is beneficial, the application usually taking the form of guano, rape-dust, or the cake left from expressing rape-oil, this last being an excellent stimulant. After this spring dressing, a double mould-board plough is passed between the drills, to throw the earth well up to the stems of the plants. The chief enemies of the crop are hail and the heavy rains of July. The harvest takes place towards the middle of July, the crop being ready as soon as the straw and seed-pods become yellow. The cutting is done by sickles, and the plants as cut are laid across the ridges, so that air may circulate well amongst them. After 6–10 days, threshing commences. A space cleared in the field is covered with sail-cloth, and to this the sheaves are brought by means of a light hand barrow lined with canvas. Great care is necessary in handling the stems, as the seed falls out very readily. The threshing is done with flails, the slightest stroke sufficing. The grain is stored dry, and needs constant turning to prevent its heating and spoiling. The colour and strength are also better preserved by the admixture of a certain quantity of husk with the seed; but nothing will obviate the necessity for repeated turning and thorough ventilation.

A second French mode of growing resembles Scotch turnip-culture. The seed is sown in drills, with guano, bone-dust, or other manure, in spring and in damp weather. Transplanting is not adopted, but the plants are thinned out, as if raising swedes for seed. The crop is nearly as heavy as that obtained by the other method, and the cost is greatly diminished by the saving effected in labour.

In India, rape-seed is very commonly sown mixed with mustard-seed, and almost always as an auxiliary with grain crops. It prefers loams, and does not flourish on clay soils. The sowing takes place in October, and the harvest in the following February, the plants being cut somewhat prematurely, or the pods would burst, and much of the seed be lost. The latter is ripened by exposure to the sun for 3–4 days on the threshing-floor, and is then easily dislodged.

The yield of seed per acre, and of oil from the seed, vary exceedingly, principally according to the soil, the season, and the care bestowed. Rotation of crops is as necessary for this as for every other culture. A crop that stands well and thick on the land does not always yield the most oil. In France, the seed is estimated to average 20 bush. an acre and often exceeds that figure; and the product of oil is calculated at 50 lb. (unrefined) from 22 gal. of seed. There are no available statistics showing the seed-crop per acre in India; but the Indian seed known as "Guzerat rape," largely crushed at Dantzig, is found to yield 3½ per cent. more oil than European seed, and leaves a cake richer in fatty matters and albuminoids; it is shipped from Bombay, and brings the highest price of any.

In France, colza-culture extends throughout the regions of the north-west and the plains of the north, but is little known in the south, and in the mountains of the centre. The chief departments engaged in raising this crop are Pas de Calais, Calvados, Seine-Inférieure, Nord, Somme, Saone-et-Loire, and Eure. The industry is declining before the extensive imports of mineral oils from America. In 1873, there were 415,491 acres under the crop, which yielded 6,541,718 bush. of seed; and in 1877, 344,187 acres afforded 5,992,591 bush. of seed. Considerable quantities of rape-seed are produced in Germany and Belgium, and much is imported in addition. The expression of the oil forms a large industry at Dantzig and Stettin. The former crushed 12,500 tons of rape-seed in 1879, exporting 88,000 cwt. of oil; of this, 2600 cwt. refined and 35,000 cwt. crude were exported to England. The total exports in that year were 92,833 cwt., value 127,650*l.*, as against 77,922 cwt., 124,675*l.*, in 1878. Memel shipped 2532 cwt., value 1266*l.*, in 1879. A great deal of rape-seed is grown in Hungary, but the area sown varies remarkably. During the years 1854–77, the annual production has fluctuated between 6300 and 123,900 tons of seed, averaging 38,882 tons; the crop of 1877 amounted to 100,000 tons. In the countries bordering the Danube, colza grows both wild and under cultivation. The shipments of seed from Roumanian (Danube) ports increased from 52,882 quarters in 1874 to 86,754 in 1879; in 1877, they were only 16,065 quarters (wild); in 1878, 117,297. The exports from Galatz in 1879 were 4087 quarters. Denmark exhibits a downward tendency in the cultivation of this crop, the number of acres occupied by it being 35,330 in 1866, and 1272 in 1876; the production in 1878 had fallen to 23,000 bush. Quantities of rape-seed are exported from Russia; the shipments in 1879 were 69,153 quarters from Nicolaieff, 71,572 from Taganrog and Rostov, 15,712 from Mariopol, 5149 from Yeisk, and 255 from Genitchesk. Wild rape is dying out in the Nicolaieff district, and being replaced by cultivated. The produce is shipped chiefly to N. France. The rape-crop is very general throughout India, and is growing in importance, the shipments of seed having increased from 359,854 cwt. in 1873–4, to 3,193,488 cwt. in 1877–8. The Chinese district of Ichang produces large quantities of colza-oil.

Colza- or rape-oil has a sp. gr. of 0·912–0·920, and congeals at—6° (21°F.); its colour is brownish-yellow, and it acquires a nauseous odour and flavour by keeping. It consists of 54 per cent. oleine and 46 per cent. stearine; as extracted, it contains much mucilage, which is removed by treatment with 2 per cent. of sulphuric acid; this operation diminishes the colour and density of the oil. As the purified oil ages, it becomes whiter and more viscous, and increases in density, at the same time losing its combustibility, and burning with a most unpleasant smoke; it is very slightly soluble in alcohol, and is itself a solvent of sulphur and phosphorus. Formerly, the chief application of the oil was for illuminating purposes, and it is so still in India; but in Europe, it is used as a lubricant, and is employed extensively by indiarubber manufacturers.

Coquito-oil.—This is said to be obtained from the fruits of a palm, *Elæis melanococca*, gathered in immense quantities in the states of Oaxaca, Colima, Guerrero, and other portions of Mexico, though the name *coquito* is applied in Chili to another palm, *Jubæa spectabilis.* The yield of oil is stated at 50 per cent.; it is solid at the ordinary temperature of the central portion of the country; and is manufactured into soap of very fine quality.

Cotton-seed-oil (Fr., *Huile de Coton*; Ger., *Baumwollensamenöl*).—The seeds which are separated from the "lint" or "wool" of the various kinds of cotton in the process of "ginning" (see Fibrous Substances—*Gossypium*, p. 948) are valued for their oil. The utilization of this oil is assuming the importance of a distinct industry in the United States, where there are now upwards of 40 oil-mills, 9 being situated in Mississippi, 9 in Louisiana, 8 in Tennessee, 6 in Texas, 4 in Arkansas, 2 in Missouri, 2 in Alabama, and 1 in Georgia. The quantity of seed treated for its oil now amounts to over 400,000 tons annually, and the increasing production of the oil may be gathered from the following figures, showing (*a*) the number of gallons exported, and (*b*) the home consumption:—year 1876–7, *a* 1,316,000, *b* 2,000,000; 1877–8, *a* 1,457,000, *b* 1,800,000; 1878–9, *a* 5,750,000, *b* 2,425,000. The American process of extraction is as follows. The seed coming from the ginning operation (see p. 957) still has some fibre adhering to it, and has a tendency to accumulate in masses. These are thrown into a machine containing a screw-knife revolving in a trough, which divides the materials into particles fit for the screening operation. This is conducted first in a sieve with meshes that allow the sand and dirt to pass, while retaining the seed; and then in one through which the seed can escape, but not husks and coarse foreign matters. The cleaned seed is next passed through a special gin for removing all remaining fibre (useful for paper-making and other purposes); and finally through a hulling-machine or decorticator, consisting of fixed and revolving knives set so close as to sever the seeds. The huller made by D. Kahnweiler, 120, Center Street, New York, was favourably noticed at the Centennial Exhibition. Thus treated, the seeds are taken through one or more separators, which pass the kernels but retain the shells. The kernels are pressed into cakes between iron rolls, and are then placed in steam-jacketed iron tanks, 4 ft. wide and 15 in. deep, where, by constant stirring, and the action of dry heat obtained from injecting steam at 35 lb. a sq. in. into the jacket, the oil is liberated from the cells in the course of about 5 minutes. The heated mass is then filled into sacks and subjected to repeated hydraulic pressure, till most of the oil is extracted. This process of extraction is replaced in England by an improved method, described under a separate heading in the present article, see p. 1451. By the American plan, the yield from 1000 lb. of seed averages 490 lb. of husks, 10 lb. of cotton, 365 lb. of cake, and 135 lb. of oil.

In India, cotton-seed is used more as a cattle-food direct, than as an oil-yielder. By the native mills, it affords 25 per cent. of a good oil, which, if purified, might become of considerable commercial importance. The seed cannot safely be shipped without undergoing preliminary cleansing, otherwise it heats and deteriorates in bulk on the long voyage. Egypt exports large quantities of the seed to Marseilles and English ports; the total exports for the season 1879–80 were estimated at 2,200,000 *ardebs* (260,000 tons), value 1,750,000*l.*, of which, 98⅝ per cent. was for the United Kingdom; the official figures are 1,282,770*l.* worth to Great Britain, 66,200*l.* to France, and 100*l.* to Turkey. The Turkish port of Adana shipped 3,389,375 lb. of cotton-seed, value 6740*l.*, in 1878; and Bagdad exported 134 cwt., value 189*l.*, to Europe and India in the same year. Quantities of cotton-seed oil are produced in Ichang (China). The native imports of this oil at Hankow in 1879 were 1333½ *piculs*, value 2493*l.* The export of native-grown cotton-seed-oil from Shanghai to Chinese ports in 1879 was 1309½ *piculs.*

The yield of oil varies with the season and the locality in which the seed is produced. In the United States, it is reckoned that for each 1 lb. of ginned cotton there are 3 lb. of seed, or a total approaching 4000 million lb., half of which only is required for sowing. One authority estimates that 100 lb. of seed give 2 gal. of oil, 48 lb. of oil-cake, and 6 lb. refuse fit for soap-making; another says that 1 ton of American seed gives 20 gal. of oil; a third, that the oil product is 37 per cent. of the weight of the kernels; a fourth, that 2 gal. of oil and 96 lb. of cake are afforded by 1 cwt. of seed; a fifth, that 1 ton of cotton material yields at the rate of some 35 gal. of oil. The crude oil is often dark and turbid; when refined, it assumes a dark sherry-colour, has a pleasant, sweetish flavour; sp. gr., 0·925–0·9306; congealing-point, 1° (34° F.); and is largely used in adulterating other oils, as linseed-oil, sperm-oil, and lard-oil, for painting, burning in lamps, and lubricating. It is extensively mixed with olive-oil, and often replaces it altogether; as a preventive measure, the Italian Government has levied a heavy duty on its importation. Large quantities of it are consumed by soap-makers, in combination with other oils and fats. For lubricating purposes, some manufacturers prepare a "winter oil" from it, which does not thicken in cold weather, by precipitating and removing the stearine; but its gumminess must limit its application. Its value in New York is about 18–20*d.* a gal. The cake remaining after the expression of the oil is invaluable as a cattle-food and as a fertilizer, and is an important article of commerce. In 1880, Galveston (U.S.) exported 399,841 lb., of cotton-seed, value 459*l.*; and New Orleans, 255 sacks of cotton-seed, and 8137 barrels of the oil, besides 3480 barrels of "soap-stock."

Coumu-oil.—Three or more species of *Œnocarpus* which are common on the Amazon, notably the *patawa* (*Œ. Batawa*), the *bacaba* (*Œ. Bacaba*), and *Œ. disticha*, bear oleaginous nuts, whence the Indians extract clear, fluid, greenish-yellow oils, which, when purified, are inodorous, of sweet flavour, excellent for cooking and lighting purposes, and used in Pará for adulterating olive-oil. The second-named is said to make good soap.

Crab-, Carap-, or Andiroba-oil (Fr., *Huile de Carapa*; Ger., *Carapafett*).—The nuts of *Carapa guianensis* [*Xylocarpus Carapa*, *Persoonia guareoides*] afford a fatty oil. The tree grows numerously in the forests of Guiana, where it is called *carapa* and *andiroba*; it is found more or less commonly throughout tropical America and the W. Indies. It is remarkably abundant in Brazil, and any quantity of the oil can be obtained at Pará and Manaos. The nuts are so plentiful in the district of Cachipour, in French Guiana, as to cover the ground for more than a foot in depth over an area of several miles. There is a dual harvest—in June–July, and again in October. The oil is extracted from them in the following manner:—The seeds are boiled without being shelled, and exposed to the air for 8–10 days, to allow the oil to develop itself; they are then removed from the shells, and ground into a paste, which is placed in vessels exposed to the sun, taking care to set them on an incline, so that the exuding oil may run off. This first-run oil, ordinarily quite fluid, is put aside for domestic applications. The residue, on being pressed, yields another product, having the consistence of grease; this is less esteemed, and is used only for lighting and similar purposes. The excessive bitterness of the oil repels all insects, and it is therefore used for anointing, and for preserving wood. For the former application, it is extracted by peeling the seeds and exposing them to the sun on long strips of bark, inclined so that the oil may escape into receptacles; this is then mixed with annatto, and takes the name of *touloumaca.* For application to timber, the oil is mixed with pigments or tar. The yield of oil from the seeds amounts to 70 per cent. of their weight. The oil acquires a solid consistence in Europe. It contains a large proportion of stearine, associated with oleine and margarine. It makes an excellent soap, and is said to be a valuable lubricant, protecting iron and steel from rust in a remarkable degree. It received a prize medal at the Exhibition of 1851. Similar products are Mote-grease, and an oil obtained from *Carapa moluccensis* (see pp. 1395–6).

Croton-oil (Fr., *Huile de Croton, de Graines de Tilly, de Graines des Moluques, de petits Pignons d'Inde*).—The valuable medicinal agent known as croton-oil is obtained from the seeds of *Croton Tiglium* [*Tiglium officinale*], and what are probably equally useful oils are afforded by several other species, noticed below. *C. Tiglium* is a small tree (15–20 ft. high), indigenous to the Malabar Coast and Tavoy, and found cultivated in gardens in Bengal, S. India, Ceylon, Burma, the Indian Archipelago, the Moluccas, and even in Mauritius. The fruits contain 3 seeds, measuring ½ in. long and ⅔ in. broad, whose kernels afford 50–60 per cent. of fatty oil. This is extracted by grinding the kernels, and pressing the meal in bags between iron plates; the oil is allowed to stand for 15 days before being filtered. The solid residue from the expression is saturated with twice its weight of alcohol, and heated on a sand-bath at 49°–60° (120°–140° F.); the mixture is pressed again, the alcohol is distilled off, and the oil is filtered after standing for a fortnight. The product obtained by this process from 2 lb. of seed is 6 fl. oz. of oil by the first expression, and 5 fl. oz. by the second. Occasionally the seeds are roasted before being pressed. The oil is orange-yellow or sherry-coloured, of the consistence of nut-oil, with a slight odour resembling that of jalap-resin, and an acrid flavour. It is powerfully cathartic. Its sp. gr. is 0·942. It becomes turbid at a moderate degree of cold, and, exposed to the air, slowly changes to a thick viscous mass. It dissolves in 23 parts of alcohol of sp. gr. 0·848, but its solubility in this medium seems to vary according to the age of the oil and the freshness of the seeds yielding it, and increases as it becomes more oxidized. The oil consists largely of stearic, palmitic, and other fatty acids combined with glyceryl as fats, but contains other bodies which are the origin of the peculiar properties that render the oil serviceable in medicine (see Drugs, p. 809). The oil prepared in India is largely adulterated with castor-oil and the oil of the physic-nut. The seed is therefore imported, in cases, bales, or robbins, chiefly from Cochin and Bombay, and the oil is expressed in this country by one firm only, it is believed. Precautions are necessary in handling the seed and extracting the oil, on account of the powerful ill effects manifested upon the workmen. Medicinal oils having precisely similar applications among native practitioners, but which have not yet been scientifically investigated, are yielded by the seeds of *C. oblongifolium* in Bengal, *C. Pavanum* in Assam and Burma, especially Camrup and Ava, and *C. polyandrum* [*Baliospermum montanum, polyandrum, indicum*; *Jatropha montana*] in S.-W. India, Bengal, Nepal, Sikkim, and Burma.

Dika-fat.—The seeds of *Irvingia Barteri*, the *dika* of W. Africa, afford 60 per cent. of a solid fat resembling cacao-butter, fusing at 30°–33° (86°–91½° F.), containing myristine and laurine, and capable of making very fine soaps. Much of the dika-fat imported into this country is almost as hard as stearine, with a reddish colour from suspended impurities, and a fatty acid melting at above 49° (120° F.); its soap is very hard.

Dilo-, Domba-, Pinnay-, Poon-seed-, or Tamanu-oil.—This oil of many names is the produce of *Calophyllum inophyllum* [*bintagor*], a large and very handsome forest-tree, of wide distribution in the E. tropics. It is found in the western peninsula of India, from Concan and Orissa southwards; in Ceylon; in the eastern peninsula, from Pegu southwards; in the Andaman Islands; in Java and the Malay Archipelago; and in most of the island groups of the S. Pacific, as the Fiji, Society, Marquesas, Cook's, and New Caledonia Islands. The tree prefers a moist sandy soil, thrives best within the range of sea-breezes, and is even not averse to land impregnated with salt water. Commencing almost on the sea-beaches, it follows the streams up the valleys, spreading where the ground is suitable; but inland it is of rare occurrence, and probably will not grow beyond a certain distance from the sea. It propagates itself with great readiness, the seeds germinating where they fall in the shade of the parent tree; they may be transplanted when 9–10 in. high without risk, needing an occasional watering, and protection from cattle, till 5–6 ft. high. Commonly the seeds are sown in the place which the trees are intended to occupy, without any transplanting. The trees are fruitful at the 5th year, and yield 2–3 harvests of oil-seeds annually, according to the locality. In Bengal, Orissa, Madras, Travancore, and S. India generally, there are usually 2 crops yearly, in August-September and February–March, though the tree is in flower and fruit during the greater part of the year. When three gatherings are made, they take place in June–July, November–December, and February–March. In Tanjore, 437 acres are occupied by this culture, the produce being an average of 24⅝ *cullums* of seed per acre, yielding 2670 *maunds* of oil. A nursery of young plants has been started in British Burma, and promises to be a complete success as an industrial enterprise. In the Andamans, the tree attains an enormous size. In Java, it is largely cultivated for its shade and fragrant flowers, and is called *njamplong* and *bientangoor*. Formerly, it was exceedingly abundant in Tahiti, and is still to be found there in great numbers in some districts, though the natives have cut down very many for the sake of the timber, which is highly esteemed for some purposes (see Timber—*Calophyllum*).

The fresh seeds when shelled afford a large quantity of oil, amounting even to 60 per cent. by weight. In India, this is extracted in the following manner. The mature seeds are gathered, and beaten with a small wooden hammer or similar instrument, to separate the shell from the kernel; the latter is then cut into slices, sun-dried, and triturated in the common country mill. The result is a yield of about 33 per cent. of a dirty, dark-green, disagreeably odorous oil, the thickness and depth of colour augmenting with the age of the seed. No method of refining is attempted. The cake is used as fuel, and sometimes for illuminating, but is not consumed as cattle-food, nor applied as a manure. It is said that, in the Calcutta market, this oil cannot compete with castor-oil for industrial purposes in its present crude condition, though in Burma it fetches about 4 times the Calcutta price of castor-oil. Doubtless it might be very much improved by extracting it by means of simple hydraulic pressure, instead of subjecting it to the friction of the mill. In the Society Islands, the kernels are exposed to the sun for about two months, reduced to powder, and pressed in linen sacks. When the oil ceases to run, the cakes are broken up, exposed to a gentle heat to coagulate the albumen, and again put under the press. Thus a second flow of oil is induced. The first exudation would be much facilitated by warming the powder, but the product then becomes much more quickly rancid. The usual results of the operation are stated thus:—100 lb. of entire nuts give 39 lb. of kernels; 100 lb. of kernels give 41 lb. of oil by the first expression, and an additional 40 lb. by the second, or a total of 81 per cent. In Fiji, the mature fruits are allowed to fall to the ground, and lie until the fleshy covering has rotted. The remaining kernels in their shells are baked on hot stones; the shells are then broken, and the kernels are ground to powder. The macerated mass is then placed in an exceedingly rough kind of filter-press, made of the fibre of one or more species of *Hibiscus* (see Fibrous Substances, pp. 961–2), and thus a portion of the oil is extracted. The pressure is quite inefficient, and much of the oil is thereby wasted. It will be noticed that preliminary heating of some sort is common to all the processes, probably indicating that the oil does not exist ready formed in the kernels, but is developed by heat.

The oil varies in colour from greenish-yellow to deep-green, possesses a peculiar disagreeable flavour, and an odour which is described as fragrant by some but unpleasant by others. These qualities are all ascribed to the resin which it holds in solution. The oil may be separated from this resin by treatment with alcohol, the resin being dissolved by this agent, while the oil remains insoluble. The latter is also insoluble in ether and chloroform. Treating with 2 per cent. of sulphuric acid, and subsequently washing with hot water, is perhaps a simpler and cheaper method of purifying the oil. The sp. gr. of the oil is 0·9347. Its congealing-point and boiling-point are not known; it is liquid at ordinary temperatures, begins to thicken when cooled below 10° (50° F.), but is said not to be solid at −4° (25° F.). Locally, the oil has a great reputation as a remedial agent in rheumatism and similar affections; it is also employed for ointments, and largely as an illuminator, but not for culinary purposes. As regards its future utility, experiments show that, when freed from the resin, it makes an excellent, coloured, aromatic soap; it mixes readily with pigments, and, applied as paint, whether previously boiled or not, dries completely within 12 hours. Formerly there was a considerable export of the oil from Madras, the shipments in 1847–8 having been 3871 gal. of the oil and 508 cwt. of the seed, to Ceylon and the Straits.

The tree further affords a resin (see Resinous Substances—Tamanu).

The seeds of the Indian species *C. Walkeri* [*decipiens*] of S. India and Ceylon, and *C. Wightianum* [*spurium*, *decipiens*] of the mountains on the W. coast of the W. Peninsula, yield oils differing but little from that obtained from *C. inophyllum*, and are probably the sources of the oil erroneously referred to *C. Calaba*, which is not an E. Indian tree. Other species afford Calaba- and Keenatel-oils (see pp. 1379, 1392), the former in the W. Indies, the latter in Ceylon.

Dogwood-oil.—The berries of the dogwood (*Cornus sanguinea*), in Italy, Siberia, and Cashmere, are utilised for their oil. It is extracted by crushing the entire berries, boiling them, and skimming off the oil as it rises: the albumen is then removed by boiling the crude oil in water strongly acidulated with sulphuric acid. Properly prepared, it is edible, and said to be so applied in Italy; more usually it is applied as a lamp-oil; it also makes good soap. In Germany, an illuminating-oil is obtained from another so-called "dogwood-" or skewerwood-tree (*Euonymus europæus*).

Gamboge-butter.—The seeds of the *Garcinia pictoria* (see Pigments—Gamboge), a good-sized tree, common in the forests of Coorg and W. India generally up to 3500 ft., afford a yellow-coloured semi-solid fat, which is used by the better natives as a lamp-oil, and by the poorer as a substitute for *ghee*. It is extracted by pounding the seed in a mortar, and boiling the paste until the oil rises to the surface.

Gingelly-, Sesame-, Til-, or Benné-oil (Fr., *Huile de Sésame*; Ger., *Sesamöl*).—Gingelly-oil, whose name is variously spelt, is obtained from the seeds of *Sesamum indicum* [*orientale*], an annual plant 2–4 ft. high, indigenous to India, but long since propagated by cultivation in almost all tropical and sub-tropical countries, and now found nowhere in the wild state. There appears to be only one true species, but Indian cultivators distinguish two varieties—a white-seeded, called *suffed-til*; and a black-seeded, called *kala-til*. The two kinds are by them never sown together, but each is grown as a mixed crop with other plants. The white-seeded, commonly called "second sort," is sown in June, and ripens in August; the black-seeded, or "first sort," which is much the more common, is sown in March, and ripens in May. The mode of cultivation usually adopted is sufficiently simple. Ploughing is commenced towards the end of February, and is completed before the middle of March. If no rain has fallen some time previously, the field is irrigated; it is then ploughed three times, the seed being sown broadcast immediately before the 3rd ploughing, by which it is covered. Sometimes manuring and weeding receive attention, and occasionally a second irrigation is given. The soil preferred is red loam, but sand is also suitable. The crop is generally considered exhausting. It is commonly reckoned that an acre requires $\frac{1}{16}$ bush. of seed, and yields $1\frac{1}{2}$–2 bush., occupying the land for about 3–4 months. When ripe, it is cut down, and stacked for 7 days; it is then sun-dried for 3 days, being collected into a heap at night, and kept in heap on alternate days between the sun-drying. This causes the bursting of the pods and the liberation of the seed. The latter is subjected to frequent washings in cold water, and subsequent exposure to the sun, with the object of bleaching it, and the oil is extracted by pressure. In India, the common yield is 2 qt. of oil from 9 lb. of seed; it may be said to range between 45 and 50 per cent. by the commercial processes in vogue, though it is present to the extent of 56 per cent. and upwards.

In Europe, the plant does not succeed well so far north as S. France; it is grown on a very small scale in N. Italy (near Bologna and Lucca), Sicily, Malta and Gozo, and to some extent in portions of Greece and Turkey; Gallipoli exported 945 quarters, value 4080*l.*, in 1871; and the two Greek provinces of Calamata and Messenia produced 68,000 lb., 535*l.*, in 1880. In most parts of Asia, it is a familiar crop. The Turkish dominions produce very large quantities of the seed, as may be judged from the fact that, in 1878, the port of Adana shipped 9,736,787 *kilo.*, value 92,795*l.*; Aleppo, 1227 tons, value 22,086*l.*, to France, 108 tons, 1944*l.*, to Turkey, 59 tons, 1062*l.*, to Italy, and 4 tons, 72*l.*, to Egypt, total, 1398 tons, 25,164*l.*; Bagdad, 1380 cwt., 843*l.*, to Europe; and in 1879, Jaffa exported 13,750 tons, value 24,444*l.*, to Europe. The Jaffa produce goes almost entirely to Marseilles, where it is highly esteemed as affording the finest culinary oil. The Persian exports in 1879 were 10,500 *rupees*' worth of seed from Bushire, and 6500 *rupees*' worth of oil from Lingah. There are few districts in India that do not cultivate the plant; but the culture might be immeasurably extended, and the seed (or oil) be remuneratively exported to Europe. The Madras presidency is said to have 870,000 acres under this crop, chiefly in the Godavery district. The white seeds produced in Sind are said to yield the finest Indian oil. The exports of seed from India were 1,039,687 cwt. in 1879. Ceylon grows large quantities of gingelly-seed. Eastwards and northwards, the culture extends throughout the Corea, Siam, China, Formosa, and Japan. Bangkok exported 50,000 cwt. in 1868, and 77,000 cwt., 183,009*l.*, in 1870; the exports in 1875 from Siam were 13,193 *piculs* (of $133\frac{1}{3}$ lb.), value 21,003*l.* Formosa exported 46,000 *piculs* of seed in 1869, but only 3700 cwt. in 1871. Kiungchow exported 12,295 *piculs*, value 12,832*l.*, in 1877, $13,011\frac{1}{4}$ *piculs*, 13,979*l.*, in 1878, and $21,864\frac{1}{3}$ *piculs*, 23,127*l.*, in 1879. Chefoo exported 329,745 lb., value 1368*l.*, of gingelly- and mustard-seeds in 1878. The total exports and re-exports from Hankow in 1878 were $352\frac{1}{2}$ *piculs* of seed, and $320\frac{1}{2}$ *piculs* of oil; the exports of oil alone in 1879 were 201 *piculs*, value 333*l.* Much oil is produced in the district of Ichang. Shanghae, in 1879, imported $7094\frac{1}{2}$ *piculs* of native gingelly-seed, $1375\frac{1}{4}$ being for local consumption; the exports were $382\frac{1}{4}$ *piculs* to foreign countries, 150 to Hong Kong, and $1645\frac{1}{2}$ to Chinese ports. Taiwan exported $1963\frac{1}{2}$ *piculs* of seed in foreign bottoms in 1879. Among African countries, Egypt stands first, affording the chief supplies for the European markets, especially Marseilles, where the expression of the oil is extensively carried on. From Egypt, the culture has spread to Morocco; from Tangier, 92 cwt. of the seed, value 115*l.*, were shipped to Great Britain in 1878. In E. Africa, the plant grows everywhere on the coast, and extends far into the interior, Mozambique and Zanzibar furnishing considerable quantities of the seed. The mode of extraction practised here is to pound the dry seed in a mortar, adding a little hot water when the oil begins to appear, and then squeezing the mass with huge pestles; the supernatant oil is ladled out as it exudes. On the W. coast of Africa, gingelly-culture is becoming popular. Senegal exported 600 cwt. of the seed in 1870. Lagos (where it is called "beni-seed") shipped 729 tons in the same year; but since that date, there is a remarkable falling off—46 tons in 1875, 284 in 1877, and 43 in 1878. All over Angola it should become an important product, as the plant will grow near the coast, in soil too arid for the ground-nut. On the American continent, the plant ranges from the United States, through Central America, into British Guiana, and other portions of S. America, besides being grown in the W. Indies. In the United States, it flourishes in poor, dry, sandy soils, scarcely fit for any other crop, and receives no manure. The seed is sown in drills, 3–4 ft. apart; the plants are thinned to 12 in. or more in the drill, and kept clear of weeds. Sowing takes place as soon as the frosts are over; in the Gulf States, it lasts from 1st April till June. In the autumn, the leaves fall off before the pods expand, and are left to manure the land. The stems are then cut, bound in sheaves, and stacked in the field to dry for a few days, taking no harm from rain. When the pods are quite dry, they are simply shaken over a large sheet spread on the ground. The yield of seed is estimated at 20 bush. to the acre, but much is probably wasted. In Georgia, the return of oil is found to be $9\frac{1}{2}$ gal. from 3 bush. of seed.

In France, where this oil is very largely prepared, it is usual to subject the Levant seed, which is considered the best, to three processes of expression. After the first simple expression, affording superfine (*surfine*) oil, the cakes are softened with cold water, and again pressed (*pression à froid* or *froissage*), and finally they are treated with steam and hot water for a third pressing (*pression a chaud* or *rabat*). The average product from 100 lb. of seed is 30 lb. of oil by the 1st pressure, 10 lb. by the 2nd, and 10 lb. by the 3rd. Calcutta seed gives only 47 lb.: 36 lb. by the *pression à froid*, and 11 lb. by the *pression à chaud*. Bombay seed affords also 37 lb.: 25 lb. superfine, 11 lb. by the *pression à froid*, and 11 lb. by the *pression à chaud*. This last is contrary to the experience of Dantzig seed-crushers, as mentioned previously. The commercial oil has a sp. gr. of 0·923 at 15° (59° F.), and some extracted by ether, 0·919 at 23° (73½° F.). This latter solidified at 5° (41° F.), becoming turbid at several degrees above this point; yet the congealing-point of the ordinary oil is placed at 0° (32° F.) by Prof. A. B. Prescott, and at −5° (23° F.) by Dr. Pohl. It commences visible ebullition at 100° (212° F.). At ordinary temperatures, it is more fluid than ground-nut-oil, and is less liable to change under the influence of the air; indeed, when well prepared, it is said to keep for years without manifesting any rancidity. The oil is essentially composed of oleine, which is sometimes present to the extent of 76 per cent., but it is not invariable in commercial samples. Among the other fatty acids, are stearic, palmitic, and myristic. The oil is frequently adulterated with ground-nut-oil. It is said that 10 per cent. of gingelly-oil in admixture with other oils may be detected by shaking 1 grm. of the oil with 1 grm. of a mixture of sulphuric and nitric acids previously cooled, when a fine green colour is produced which no other oil exhibits. The local uses of gingelly-oil are for cooking, medicine, anointing the body and hair, absorbing the fugitive odours of plants, and illumination. In Europe, the superfine quality largely replaces olive-oil for domestic purposes, and the other grades are employed by soap-makers.

Gold-of-Pleasure-oil (Fr., *Huile de Cameline*).—The plant known in England as "gold of pleasure" (*Camelina sativa* [*Myagrum sativum*]) is cultivated to a considerable extent on the Continent, for the sake of its oleaginous seeds. It thrives on light, shallow, dry soils, and the crop scarcely fails on land of the poorest description. It is very hardy, enduring both drought and wet; and, grown as a rotation crop, is said to allow the ground to recover itself, doing well after corn-crops. In S. Europe, it matures so rapidly that two crops are taken off in a season; in the colder portions of the Continent, as N. France, Germany, Holland, and Belgium, though not giving a double harvest, it may be sown in June–July, when other crops have failed, or, if sown early, can be removed in time for root-crops and grasses. The spring sowing usually takes place in March–April; the autumn, in August. The quantity of seed required is about 14 lb. an acre; it is sown either broadcast, or in shallow drills 10–12 in. apart. It is ready for the sickle about 3 months after appearing above ground; the seed is ripe when the pods change from a green to a golden colour, and care must be taken to cut the crop before the seed is too ripe, or much will be lost. The stems when reaped are bound in sheaves, stacked, and threshed like other grain. Over 30 bush. of seed, yielding 540 lb. of oil, have been obtained from an acre. The oil is extracted by pressure, much in the same manner as other seed-oils. It has a clear golden-yellow colour, and peculiar, mild odour and flavour; its sp. gr. is 0·925 at 15° (59° F.); it congeals at −19° (−2° F.), forms a soft soap, and dries rapidly in the air. When fresh, it burns well, without smoke. It is much used in the localities of production as a lamp-oil; also for dressing woollen goods, making soft-soap, and in painting. The chaff from the seeds is eaten by horses, but the oil-cake is too acrid for cattle-food when used alone. The stems yield a fibre (see p. 934).

Grape-stone-oil (Fr., *Huile de Pepins de Raisins*).—The "stones" or seeds of the common grape (*Vitis vinifera*), elsewhere described (see Beverages, p. 432; Fruit, p. 1027), have been utilized for their oil in Europe for more than a century. In S. France, it is computed that an average of 1 lb. of seeds is furnished by the grapes converted into 1 gal. of wine, so that the production is considerable as a whole. The seeds of black grapes contain much more oil than those of white ones; and those obtained from vines in full vigour are more oleaginous than those gathered at other periods. Generally speaking, the seeds of black grapes give 15–18 per cent. of oil; of white ones, 10–14 per cent. In France, the vines of Roussillon, Aude, and Hérault afford the most oil. It is probable that American, especially Californian, vines may yield more oil than French vines. The preparation of the oil from grape-seeds is largely carried on in S. France, and in those parts of Italy where vine-culture is common, and olive-culture is rare, notably Lombardy.

The seeds chosen for the purpose are separated as promptly as possible from the refuse resulting from the distillation of brandy (see p. 201) or the manufacture of verdigris (see p. 30); they are rendered perfectly clean, and most completely dried in the sun and air, and are then ground to a fine flour in ordinary mills, the fineness of the grinding having a direct influence on the yield of oil. Some manufacturers first subject the flour to a cold expression, and extract about 5 per cent. of oil, afterwards repeating the pressure with heat, and obtaining an additional 10–15 per cent. A more detailed operation sometimes adopted is as follows. The flour is moistened with a little water as fast as it emerges from the mill, and is then thrown into open boilers; a hole is made in the middle of the flour by the hand, reaching to the bottom of the vessel, and into this some water is poured; a slow fire is then kindled under the boiler, and the contents are unceasingly stirred, to thoroughly incorporate the water with the flour; the fire is withdrawn as soon as the heat is greater than can be borne by the hand inserted in the mass, and the latter is placed in bags and immediately pressed.

The oil has a clear yellow colour when fresh, becoming brownish-yellow with age; it is inodorous, and of faint flavour. Its sp. gr. when new is 0·918; in a short time, it increases to 0·920 at 15° (59° F.). It solidifies at −13°– −16° (9°−3½° F.); becomes viscid and rancid when exposed to the air; and saponifies readily, but gives a soap lacking hardness and density. It is said to contain chiefly erucic acid, with some stearic and palmitic acids, combined as glycerides. The fresh oil is used in Italy for culinary purposes, being considered superior to nut-oil, and but little inferior to olive-oil. It is valuable for illuminating, emitting a bright light quite free from smoke. It has been recommended as a lubricator, on account of its low congealing-point, but its drying properties preclude its use in this direction.

Ground-nut- or Arachis-oil (Fr., *Huile d' Arachide, de Pistache de Terre*; Ger., *Erdnussöl*).—The ground-nut (see p. 1357) is very widely cultivated for the sake of its oily seeds. In Java, the oil is extracted by drying the seeds in the sun, and then subjecting them to pressure. In European mills, the nuts are first cleaned, then decorticated, and winnowed, by which the kernels are left perfectly clean. These are crushed like any other oil-seed, and put into bags, which are introduced into cold presses; the expressed oil is refined by passing through filter-bags. The residual cake is ground very fine, and pressed under 3 tons to the inch, in the presence of steam-heat; this affords a second quantity of oil, inferior in quality to the cold-pressed. The usual product is 1 gal. of oil from 1 bush. of nuts by the cold process, besides the extra yield by the hot-pressing. In France, where the oil is most largely prepared, 3 expressions are adopted, as with some sorts of gingelly: the first gives about 18 per cent. of superfine oil, fit for alimentary purposes; the second, after moistening with cold water, affords 6 per cent. of a fine oil, suitable for lighting and for woollen-dressing; the third, after treating with hot water, yields 6 per cent. of *rabat*, or oil applicable only to soap-making. In India, the total mean yield is 37 per cent. at Pondicherry, and 43 in Madras. The cold-pressed oil is almost colourless, of agreeable faint odour, and bland olive-like flavour. The best has a sp. gr. of about 0·918, or 0·9163 at 15° (59° F.); it becomes turbid at 3° (37½° F.), concretes at −3°– −4° (26½°–25° F.), and hardens at −7° (19½° F.). By exposure, it changes very slowly, but thickens with time, and assumes a rancid odour and flavour. As an illuminating-oil, it has feeble power, and its chief industrial uses are for soap-making and lubricating, particularly the former. Locally, it is employed for cooking and burning, and as a general substitute for olive-oil. Indeed, very large quantities are readily passed off as olive-oil in European markets. As a rule, the seeds are exported in a raw state to such centres as London, Marseilles, Bordeaux, Nantes, Dunkirk, Hamburg, and Berlin, where they are crushed, and the oil passes into general commerce without maintaining its identity. Thus statistics concerning it are meagre. Pondicherry exported 99,330 *veltes* (of 1·64 gal.) of the oil in 1860; but the most extensive foreign trade in the oil takes place with China. Thus Shanghai, in 1879, imported 1601½ *piculs* (of 133⅓ lb.) from Chinese ports, and exported 8167¾ *piculs* to Chinese ports, and 840½ to foreign countries; in 1878, the exports to foreign countries were 786 *piculs*. The lowest estimate of the annual export from Pakhoi is 90,000 *piculs*. Hankow, in 1879, imported 651 *piculs*, value 1497*l*., of native oil. The nuts from the Galam district (W. Africa) are most esteemed for their yield of oil and the thinness of their shells.

Hazel-nut-oil (Fr., *Huile de Noisettes*).—The hazel-nut (see p. 1358) affords about 60 per cent. of oil, which, in some parts of continental Europe, is extracted by pressure, in the same manner as almond-oil. It is limpid, clear-yellow in colour, and of sweet and agreeable flavour; it congeals at −19° (−2° F.) [some say at −10° (14° F.)]; has a sp. gr. of 0·924 at 15° (59° F.); and soon becomes rancid. Its chief application is for perfumery. Other wild species in India and elsewhere probably yield similar oils.

Hempseed-oil (Fr., *Huile de Chanvre, de Chènevis*; Ger., *Hanföl*).—The seeds of the hemp-plant, so well known as a fibre-producer (see Fibrous Substances, p. 934), are valued for their oil. It is from Russia and Lorraine that the seed for expressing mostly comes. When the fibrous stems are tied in bundles, the seed is rudely threshed out, and spread in thin layers under cover to dry. The extraction of the oil is performed in the same manner as with other seed-oils, described in a separate section of this article (see p. 1451). The proportion of oil contained in the seed is about 34 per cent. on an average; the yield varies from 25 to 30 per cent. The oil is at first greenish- or brownish-yellow, deepening with exposure to the air; the flavour is disagreeable, and the odour is mild. It has a sp. gr. of 0·9252 at 15° (59° F.); it thickens at −15° (5° F.), and solidifies at −25°– −27½° (−13°– −18° F.); it dissolves in 30 parts of cold alcohol and any proportion of boiling; it saponifies with difficulty, forming a soft soap, but less soft than that from linseed-oil. It is locally consumed largely for lighting, but its most important application is for making soft-soaps. The exports of hempseed from Riga were 21,011 quarters in 1875, and 78,690 in 1878; and in 1879, 725,809 *poods* (of 36 lb.) of the seed, and 573 of the oil. In 1872 (the date of the latest return), Russia had 812,630 acres under hemp, which yielded 14,410,000 bush. of seed. In France, 238,100 acres under hemp in 1874 produced 1,263,424 bush. of seed.

Hickory-nut-oil.—From the seeds of several species of *Carya* (see Nuts, p. 1358), excellent oil for illuminating and lubricating purposes has been extracted in Ohio. It continues fluid at very low temperatures, and is used for delicate machinery, and even for watches, when refined. The pig-nut (*C. glabra*) is preferred, on account of its thin shell and greater yield of oil, which is bitter. The oils from the "shell-bark" and the large sweet hickory-nut are very palatable, and might come into table use.

Horse-chestnut-oil (Fr., *Huile de Marron d'Inde, de Fécule*).—The whole fruit of the horse-chestnut (see Nuts pp. 1352–3) contains two fixed oils, one in the case, which is greenish-coloured, and a second in the kernel, of an orange-yellow tint. The proportion of oil in the kernel is very small. Chemists have detected by analysis a quantity varying from 3 to 5½ per cent., reckoned upon the green kernels; but the highest yield obtained in practice has been 1½ per cent., even when treating 2 cwt. at a time. Nevertheless some hundreds of cwt. of the oil have been made in France, chiefly by Emile Genevoix, a Parisian druggist. He employs the unpeeled kernels, and proceeds by destroying the starch present by boiling them with water acidulated with sulphuric acid, and collecting the oil which floats upon the surface. He remarks that the production of the oil is certain only when acting upon large quantities, that the water plays an important part in the operation, and that every precaution is necessary to prevent the oil being saponified during the process. The fresh oil seen in bulk is greenish-brown, with an empyreumatic odour, and a peculiar flavour; these qualities are intensified by age. It is remarkably slow to become rancid, and may be kept almost indefinitely. On the Continent, it has a great reputation as a cure for gout, rheumatism, and neuralgia.

Illipi-butter.—The almond-like fruit-kernels of *Bassia longifolia* afford a semi-solid fat. The tree flourishes in Malabar and on the Coromandel coast. The seeds contain about 30 per cent. of oil, 12½ lb. of them yielding about 2 gal. of oil by the ordinary rude native way of expressing. The oil will not keep for more than 2–3 weeks in the Indian hot season; it then becomes rancid, and emits a disagreeable odour. When well secured from contact with the air, it will keep for some months in cool weather. Its colour is usually bright-yellow, varying somewhat according to the care used in preparing it. It is eaten as a substitute for *ghee*, is burnt in lamps, and is employed in the manufacture of country soap, and for external medical application. The cakes left after the expression are used for washing the head, and form an article of trade. Fats from other species of *Bassia* are described under Mahwa-oil (p. 1394), Phulwara-oil (p. 1408), and Shea-butter (p. 1410).

Jupati-oil.—The fruit of the jupati-palm, *Raphia* [*Sagus*] *tœdigera*, which is equally or more important as a fibre-plant (see Fibrous Substances, p. 994), affords a yellowish, bitter oil, by decoction and expression, used locally for soap-making.

Kanari- or Java-almond-oil.—The *kanari* or Java almond (*Canarium commune*) is indigenous in the Moluccas, where it affords shade to the nutmeg plantations, and is cultivated also in Java, throughout the Indian Archipelago, in Malabar, and on the Indian peninsula. It bears a nut resembling the almond in shape and flavour, but much exceeding it in size. The nut affords a very large proportion of oil by simple expression. This oil is prepared by the inhabitants of the Moluccas on an extensive scale, and is in general use among them for cooking when fresh, and for burning in lamps, superseding coco-nut-oil. In India, also, the oil is employed for all culinary purposes, and is considered purer and more palatable than coco-nut-oil. The nut is very generally eaten without being deprived of its oil. The trees of this genus also afford gums or resins (see Resinous Substances).

Katiow-oil.—This is extracted by the natives of Borneo from the seeds of a tree, chiefly produced on the Sadong, Linga, and Kallekka rivers, and exported to Sarawak and other places. It is yellow-coloured, and has an odour precisely resembling almond-oil; it is valued locally for cooking and for lamps, burning with a bright flame and pleasant aroma. It is very cheap and abundant, and might be valuable to soap-makers and perfumers.

Keenatel-oil.—The seeds of *Calophyllum tomentosum* yield a great quantity of oil in Ceylon, where it is used in lamps.

Kikuel-oil.—This name is sometimes applied in India to the fatty oil of some species of *Salvadora*. It is a solid fat, of a dull, sulphury-yellow colour.

Kukui- or Kekune-oil (Fr., *Huile de Noix de Bancoul.*)—An oil bearing a multitude of names is obtained from the candle-nut (see p. 1352). It is the most important product of the tree, and constitutes about ⅔ of the entire weight of the kernel of the nut. A great obstacle to its wider development is the difficulty encountered in extracting the kernels from the shells, both on account of the extreme hardness of the latter, and the obstinacy with which the two adhere. Boiling is out of the question, as the kernels are cooked long before the shells are affected; but there is every reason to suppose that a slight roasting would have the desired effect, inasmuch as this plan seems to be adopted successfully by the Samoans. The weight of the shells necessitates this treatment being performed on the spot, and, as the kernels quickly become rancid and dark-coloured after liberation, they must also be operated upon without removal. The local cheapness of labour is an additional argument in favour of preparing the oil at the places where the nut grows. The extraction of the oil is very simple. In Jamaica, Polynesia, and the E. Indies, 50 per cent. is obtained by boiling the kernels in water; by reducing the kernels to meal, heating in a water-bath, and placing the mass in bags under hydraulic pressure, the yield is about 60–66 per cent. The shells are themselves excellent fuel. The oil is completely clarified by mere filtration. As ordinarily prepared, it is amber-coloured, tasteless and odourless; slightly viscid at the temperature of the air in England, congealing at 0° (32° F.); its sp. gr. is 0·923; it is insoluble in alcohol, and saponifies readily, giving a very soft soda-soap. It is locally used in small quantities, while fresh, in cooking and medicine; but it is much more extensively employed as a lamp-oil, giving a brilliant light, without any objectionable odour. It dries less rapidly than linseed-oil, and is used for mixing paints and making oil-varnishes. It is said to corrode tin-plate and even platinum. Its commercial value is placed at the same figure as colza- and gingelly-oils. The cake is useless as cattle-food, on account of its purging qualities, but would make valuable manure. In 1843, 8600 gal. of the oil were shipped from Honolulu (Sandwich Islands), valued at 1*s.* 8*d.* a gal.; and in 1862, the exports from the group were 10,000 gal. yearly, destined for the ports on the W. coast of S. America.

Kurung- or Poondi-oil.—The seeds of *Pongamia glabra*, a tree widely diffused in S. India, Pegu, Malacca, the Indian Archipelago, S. China, Australia, and Fiji, are expressed for the sake of their oil in several of these countries. The oil is thick, reddish-brown in colour, and has a tendency to deposit stearine in cold weather. It is used alone or combined for burning in lamps, and is much esteemed medicinally.

Lallemantia iberica.—This is a well-known plant of Syria and Persia, where it is extensively cultivated; it attains a height of 1½–2½ ft., and single plants have afforded as many as 2500 seeds, which yield a very pure culinary oil. The plant has been acclimatized at Cherson, S. Russia, for industrial purposes.

Laurel-oil.—A so-called "laurel-oil" or "bay-oil" is obtained from the fruits of the bay-laurel (*Laurus nobilis*), chiefly in Holland, Spain, Italy, and Switzerland. The fruits are peeled, ground to paste, boiled, and expressed; the oil concretes on the surface of the expressed mass when cold; it is collected, and melted in a water-bath to remove the moisture. When the fruits have been kept for some time, they are better ground and hot-pressed. The oil is used in veterinary medicine, and is found to repel flies from meat and living animals. The plant also affords a volatile oil (see p. 1422).

Linseed-oil (Fr., *Huile de Lin*; Ger., *Leinöl*).—The flax-plant, so well known as yielding a textile fibre (see Fibrous Substances—*Linum usitatissimum*, p. 964), affords a valuable oil-seed. The separation of the seed from the stems of the plant has been described on p. 967. The supplies of linseed for crushing are furnished chiefly by Russia and India. It is found that, as a general rule, the colder the climate in which the seed is grown, the greater are the drying properties of the oil, but the worse is its colour. In India, preference is given to white seed, as yielding 2 per cent. more oil, affording it more freely, and giving a softer and sweeter cake, than the red seed; the latter, moreover, always comes to market largely mixed with rape-seed, which is very difficult of separation, and greatly depreciates the market value. Oil from unripe seed is watery. The seed should always be kept for 3–4 months in a dry place, as the oil furnished after this lapse of time is much more abundant than when the expression takes place immediately after the harvest. The seed is crushed and pressed in the manner described in a separate section (see p. 1451). The best and finest oil is that which is "cold-drawn;" it is paler, less odorous, and less flavoured, but the yield is only 21–22 per cent. of the seed. By the aid of a temperature not exceeding 93½° (200° F.), and powerful and long-continued pressure, as much as 28 per cent. of very good oil can be obtained. The cake forms a valuable cattle-food. The Italian variety is said to have a much more highly oleaginous seed than the Russian.

Some 70,000 metric quintals (of 2 cwt.) of this oil are produced annually in France, chiefly in the departments of Pas-de-Calais, Somme, Nord, Maine et Loire, Vendée, Haute-Marne, Haute-Garonne, and Lot-et-Garonne; 175,772 acres under flax in 1877 produced about 1 million bush. Belgium still continues to import linseed from Russia and India. Holland had 44,114 acres under flax in 1878, and produced 446,520 bush. of linseed. The German Empire exported 586,600 centners (of 110¼ lb.) of linseed- and palm-oils in 1879; the port of Memel shipped 236,460 cwt. of linseed, value 115,000*l.*, in 1879. Sweden, in 1878, had 33,655 acres under flax and hemp, and produced 197,091 cwt. of seed. Russia has a larger trade in linseed than any other country, the exports in 1878 having been 2,684,032 *chetverts* (of 5¾ bush.); Archangel shipped 67,885 quarters in 1877, and 25,761 in 1878; of the 36,801 *chetverts* in the latter year, 19,897 went to Great Britain, and 16,904 to Holland. Riga exported 225,810 quarters of crushing-linseed in 1877, and 90,330 in 1878; in 1879, Revel shipped 43,169 *chetverts* to Great Britain; Nicolaieff, 91,818 quarters, Taganrog and Rostov, 644,204 quarters, Mariopol, 29,770; Yeisk, 83,896, Genitchesk, 214. In 1872 (the date of the latest Return), Russia had 2,247,700 acres under flax, which yielded 17,292,000 bush. of linseed. The Roumanian Danube ports shipped 4429 quarters of linseed in 1879. Kastamuni, in Asia Minor, exported 160,000 *okes* (of 2·83 lb.) of linseed, value 1500*l.*, in 1879. The total Indian exports of linseed were 7,198,918 cwt. in 1878, but only 3,503,795 cwt. in 1879. Algiers, in 1879, produced 734,795 *kilo.* of Riga linseed, and 1,384,969 *kilo.* of Italian. New York shipped 14,187 gal. of linseed-oil in 1879, and Philadelphia, 503 gal.

Linseed-oil has a faint colour, and mild odour and flavour, when pure, but the commercial article is dark-yellow, with sharp repulsive flavour and odour. Its sp. gr. is 0·930; at −18° (0° F.), a little solid fat separates out; at −20° (−4° F.), it solidifies. By exposure to the air, after heating with oxide of lead, it rapidly dries up to a transparent varnish. The fresh oil saponifies readily, giving a yellow and very soft soap with soda; by saponification, it yields 95 per cent. of fatty acids, chiefly linoleic, with a little oleic, palmitic, and myristic acids. It dissolves in 1·6 parts of ether, and in 32 parts of alcohol at 0·820 sp. gr. The oil is very extensively used in the manufacture of paint, printing-ink, floorcloth, artificial indiarubber, oil-varnishes, and soft-soap. For artists' use, it is purified by shaking up with whiting, and warming. Linseed-oil is never met with in commerce really pure, nor even the seed itself. Previous to the Crimean War, it was a recognized custom at the Black Sea ports to add 1 measure of hemp or other seed to every 39 of linseed. Since then, the proportion has advanced to 1 in 19, in addition to which, the Indian seed is grown mostly as a mixed crop with mustard and colza; pure linseed-oil can only be obtained by picking out the seeds individually. The methods of refining this oil are described on p. 1460.

Mabo.—The seeds of a plant which is thought to be a *Parinarium* have been imported into England and Germany for the sake of their oil. They have intensely hard "stones," measuring about 2½ in. by 1¼ in., and are highly oleaginous, but it is a question whether the oil can be profitably extracted. They are brought from Liberia, and are closely allied to the *mola* plum of Zambesi land (*P. Mobola*), which is supposed to be identical with the *noxa* or *nocha* (? *niko*) of Lower Guinea.

Macassar-oil.—This oil was originally obtained from the unctuous fruit of *Stadmannia* [*Cupania*] *sideroxylon*, growing in the islands of Sunda and Timor, and usually known as *kesambi*-wood. See also Safflower-oil, p. 1410, and Ilang-ilang-oil, p. 1422.

Madia-oil.—The seeds of *Madia sativa* afford some 30–40 per cent. of fatty oil. The plant is a native of Chili, where it has long been cultivated for the sake of its oil. It has been successfully introduced into Asia Minor and Algeria; its culture has also been attempted in S. France and in Wurtemburg, but without the success that was anticipated, mainly owing to the irregularity with which the seed ripens in these climates. It requires a sandy soil, and is very easily grown. In Europe, sowing takes place in October. The seeds must be threshed out soon after the stems are cut, or the latter ferment and cause injury. The seed resembles sunflower, but is much smaller. The yield of oil from an acre of the plant is rather more than from colza (rape): 1 *hectare* (2½ acres) gives 726 *kilo.* (of 2·2 lb.) of seed; and 100 *kilo.* of seed yield 32 of oil. It is extracted by expression, both cold and hot. It is deep-yellow, thick, and mild; of sp. gr. 0·935 crude, and 0·9268 at 15° (59° F.) purified; solidifies at −10° to −17° (14°–2° F.), according to the method of extraction; dries slowly; and dissolves in 30 parts of cold alcohol or 6 of boiling. The finer qualities may replace olive-oil; the coarser are used for illuminating.

Mahwa-oil.—The *mahwa* or *mhowa* (*Bassia latifolia*) is chiefly known as yielding flowers which are an important article of diet, and from which an intoxicating beverage is distilled, but it also claims notice as affording an oil. The tree is cultivated in most parts of India, and is abundant in Central India, notably in the Concans, the Circars, Bengal, Guzerat, and Rajputana. It is extremely hardy, thriving well on poor stony ground, and readily propagating itself by its seed. Its culture is therefore capable of the widest extension. The flowers are succeeded by fruits, whose kernels or seeds give some 33 per cent. of oil. The latter is obtained by bruising, rubbing, and pressing the seeds. It is greenish-yellow in colour, and of an oily consistence, when newly expressed, but immediately assumes a concrete state, remaining thus until a temperature of 43½° (110° F.) is reached. Its sp. gr. is 0·972; it is soluble in ether, scarcely in boiling alcohol. In a cool climate, the oil keeps good for a long time; but in the plains of India, it acquires a bitter flavour and rancid odour after a few months' exposure to the air, separating into a heavy brown mass below, and a little clear fluid above. It saponifies easily, and the resulting soap is good as to quality and colour, and satisfactory as to quantity. The fatty acids are easily separable, by the simple process of "training" or "seeding," described on p. 1362. The proportion of stearic acid is about 40 per cent.; it is inodorous while translucent, and is admirably adapted for candle-making. The oleine separated is superior to that from tallow and palm-oil. For industrial purposes in this country, the oil has about the same value as coco-nut-oil; it has been imported into England and France from Calcutta for soap-making. Locally, it is extensively used by Bunniahs and Muhajuns for adulterating *ghee*; it is also employed in cooking and for burning. The residual cake forms food for man and cattle; and the timber of the tree is valued (see Timber). Oils from other species of *Bassia* are Illipi-butter (p. 1392), Phulwara-oil (p. 1408), and Shea-butter (p. 1410).

Mamey-oil.—About 40 per cent. of a fixed oil bearing this name is extracted by means of expression at a high temperature from the fruit-kernels of *Lucuma Bonplandii*, in Mexico. It is employed in the manufacture of soap and cosmetics, and for illuminating purposes.

Mangosteen-oil, Brindonia-tallow, or Kokum-butter (Fr., *Beurre de Cocum, Huile de Madool*).—The fruit-seeds of *Garcinia indica* afford a fatty oil of unusual purity. The tree is indigenous to the coast region of W. India, known as the Concan, lying between Goa and Daman. The oil is extracted by the natives of India in the following manner:—The seeds are sun-dried for several days, bruised, and boiled in water; the oil escapes and collects on the surface, and, on cooling, concretes into a solid cake. The yield is about 10 per cent. The crude product needs purification by melting in a steam bath, and filtering. Thus treated, it becomes perfectly transparent and light-straw coloured, consolidating at 27½° (81½° F.) into a crystalline mass, commencing to melt again at 42½° (108½° F.), and fusing entirely at 45° (113° F.). It is composed chiefly of stearic acid, with minor quantities of myristic and oleic acids, all in combination as glycerides. It saponifies readily, and produces a fine hard soap. It is soluble in ether, and slightly so in rectified spirit. When kept long, it acquires an unpleasant rancid odour, and a brownish colour. It occurs in the Indian bazars in the form of oblong lumps, measuring 4 in. by 2 in., and weighing about ¼ lb.; it is whitish, firm, dry, and friable, yet greasy to the touch. In India, it is largely used by the natives for adulterating *ghee*, and more recently by Europeans for pharmaceutical preparations. Its present abundance does not admit of its general application to soap-making or candle-making, but it is a superior article for such purposes.

Margosa- or Neem-oil.—The fruits of *Melia Azadirachta*, and probably several allied species, afford a useful oil. The trees or shrubs are found native throughout India, and are now widely diffused in tropical and sub-tropical regions. They are hardy, and grow in almost any soil. The fruits are produced abundantly, and drop when ripe. They are gathered, and treated either by expression or boiling. Some accounts state the oil to be derived from the pulp of the fruit; others say it is obtained from the seed, the kernels yielding 25 per cent. The oil is acrid-bitter, deep-yellow, and with a strong disagreeable flavour. During the winter months in India, it becomes solid, but partially regains fluidity in summer. It is largely used by native physicians, both internally and externally; it is frequently burnt in lamps, but emits an offensive smoke; and is applicable to soap-making.

Melon- and Pumpkin-oils.—The seeds of all the members of the melon, pumpkin, cucumber, and gourd family contain appreciable proportions of oil, but the only kinds which are utilized to any considerable extent are those of the sweet melon (*Cucumis Melo*) and the water-melon (*C. Citrullus*). Considerable quantities of melon-seed, under the local French name of *petit béraf*, are collected in various parts of W. Africa, notably Senegal and Abeokuta. The production in Senegal in 1860 was 62,226 *kilo.* of the seed, which was shipped to France. China grows very large quantities of melon-seed, and has an extensive commerce in it. Thus, in 1879, Chefoo exported 4207 *piculs* (of 133⅓ lb.); Hankow, 6642 *piculs*, value 6165*l.*; Kiungchow, 1722¾ *piculs*, value 1125*l.*; Newchwang, 16,191 *piculs*. The yield of oil is about 30 per cent. The oil is clear, bland, and limpid, and closely resembles olive-oil; it is consumed as food, burnt in lamps, and made into soap. It dries slowly, and solidifies at −15° (6° F.); its sp. gr. is about 0·923.

The *egusi* oil of Abeokuta, the *abobora* of Brazil, the *ogadioka* of the Gaboon, S.-E., and S.-W. Africa, the *chocho*, and several other oils of local application, belong to this numerous and wide-spread order, the *Cucurbitaceæ*.

Moodooga-oil.—An oil is obtained from the seeds of *Butea frondosa* (see Resinous Substances—Butea kino) in India, Java, &c.; it is afforded in small quantity, is bright, clear, and fluid, and used medicinally.

Mote-grease, Tallicoona-, Kundoo-, or Coondi-oil (Fr., *Huile de Touloucoona, Tallicoona*).—The nuts or seeds of *Carapa guineensis* [*Touloucoona*], which plant has recently been declared identical with *C. guianensis* (see Crab-oil, p. 1386), afford about 33 per cent. of a valuable fatty oil.

The tree is found growing abundantly in the Timneh country and near Sierra Leone, and occurs throughout Senegal and the Guinea Coast. The seeds (18–30 in one fruit) vary in size from a chestnut to a hen's egg. The oil is extracted from them by the natives of W. Africa in the following manner:—The seeds are sun-dried, and hung up in wicker racks or hurdles exposed to the smoke of the hut-fires. After sufficient exposure, they are roasted, and triturated in large wooden mortars till reduced to a pulp. The mass is then boiled, and the supernatant oil is skimmed off. It usually forms a concrete mass on cooling, resembling frozen olive-oil, but the best samples remain liquid at ordinary temperatures. It has a pale-yellow colour, and a strong bitter flavour; the latter is due to an alkaloid principle, which is easily destroyed by boiling in water acidulated with sulphuric acid, allowing to settle, and then washing with fresh water to remove all traces of the acid. The oil is entirely soluble in ether; alcohol separates it into (1) a concrete substance, which dissolves in the alcohol, and retains the odour and flavour, and (2) an oil fluid at ordinary temperatures, and nearly colourless and tasteless. By the Africans, the oil is used most largely for lighting purposes, but is also employed as a purgative and anthelmintic. Industrially, it is capable of the same applications as crab-oil (p. 1386), and is imported into Marseilles from Senegal for soap-making. The seed is also shipped to France.

M'Poga.—The kernels of the nuts of the *m'poga* (probably a species of *Parinarium*), a tall tree abundant in the Gaboon, afford some 80 per cent. of unusually fluid oil, but difficult of extraction, on account of the hardness of the nut.

Mustard-oil (Fr., *Huile de Moutarde*).—Three species of mustard are grown more especially for the well-known condiment which is prepared from the seeds; these are *Brassica* [*Sinapis*] *nigra*, *B. alba*, and *B. juncea*; for a description of their localities and modes of culture, the reader is referred to Spices—Mustard. The seeds of these species all yield fatty oils by expression. *B. nigra* affords about 23 per cent. (over 33 with ether) of a mild-flavoured, inodorous, non-drying oil, solidifying at −18° (0° F.), and consisting essentially of the glycerides of stearic, oleic, and erucic or brassic acids, the last-named being homologous with oleic acid. The fixed oil of *B. alba* amounts to 22 per cent. of the seed, and resembles generally that of *B. nigra*. The seeds of *B. juncea*, in Russia and India, afford by pressure 20 per cent. of oil, which is used like the best olive-oil, and for burning in lamps. These oils vary in sp. gr. from 0·9142 to 0·917, and are soluble in 4 parts of ether.

Other species of mustard, whose seeds are not prepared as a condiment, but which are utilized for their oleiferous properties, are as follows:—*B. arvenis*, the charlock, yields an excellent burning-oil, and it is to be regretted that this common and troublesome weed, so abundant in Europe, has not been turned to better account. A mustard-plant thrives so well in California as to smother the corn in the fields. The seed is gathered by the Chinese and brought into San Francisco, where the oil is expressed, and used as salad-oil. *B. cernua* is cultivated for its oil in Japan. *B. chinensis* is grown with the same object in immense quantities in China, notably in the Yangtze-kiang and Han-kiang river-valleys, in the provinces of Chekiang and Kiangsu, and to some extent also in the district of Ichang, province of Hoopih. It is in seed and ready for harvesting in the beginning of May. The seed is treated by a rude press, yielding a dark-yellow, pleasantly-odorous, thick oil, used for cooking, in lamps, and for anointing the hair.

An allied oil-plant is the colza or rape (see p. 1384).

Myrobalan- and Jungle-almond-oils.—Small quantities of fatty oil are expressed from the seeds of two Indian species of *Terminalia*, *T. Bellerica*, and *T. Chebula*, plants which are much more important on account of their astringent properties (see Tannin—Myrobalans). The oil of the first species readily separates into two portions, a pale-green fluid, and a white, floccular semi-solid. It is used locally for anointing and strengthening the hair. The oil of the second species is procurable only in very small proportion; it is a clear, transparent, almost colourless fluid, of medicinal use.

A third species of *Terminalia*, the jungle-almond of India (*T. Catappa*), is much more widely distributed, and of greater importance as an oil-yielder. It is found abundantly in both E. and W. Indies, and grows freely in Mauritius and Bourbon. The fruits (nuts) are gathered, and exposed to the sun for a few days, to facilitate their breaking, which is one of the main items in the cost of extracting the oil. The kernels are next freed from shell, crushed, and cold-pressed. The oil is similar to almond-oil in flavour, odour, and sp. gr., but is deeper coloured, and deposits stearine by keeping. It is, however, very slow to become rancid; and if carefully prepared and refined, it might well replace true almond-oil and hazel-nut-oil for most purposes.

Niger, Kersanee, or Ram-til Oil.—The "Niger seed" of African commerce, and the *ram-til* or *kersance* of Indian cultivators, is the product of *Guizotia oleifera*. The plant grows wild on the Gold Coast of Africa, and is cultivated in Abyssinia, and in many parts of India, especially Mysore and the Deccan; here the seed is sown in July–August, after the first heavy rains, the fields being simply ploughed, and neither weeded nor manured. The crop is cut 3 months after the sowing, and, after being sun-dried for a few days, the seed is threshed out, the produce being about 2 bush. an acre. By the common country mills, only 25 per cent. of oil is got from the seed, but better appliances bring the average up to 35. The oil is limpid, clear, pale, and sweet-flavoured, and is used as an edible oil by the poorer classes of India, and commonly as a lamp-oil. Though much inferior to gingelly-oil, it is frequently used as a substitute for it, and to adulterate both this and castor-oil. The oil contains but little stearic or palmitic acid, hence soap made from it, though very white, is soft. The cake is an esteemed food for milch cows.

Nounga and Djave.—These two fatty substances are said to be produced by a species of *Bassia*, which has been called *B. gabonensis*, found on the Gaboon. The former has the consistence of butter; the latter is available only for soap-making. Their united yield is 56 per cent.

Nutmeg-butter or Mace-oil (Fr., *Beurre de Muscade*; Ger., *Muskatbutter*, *Muskatnussöl*).—The fixed or fatty oil obtained from the nutmeg (see Spices—Mace and Nutmeg), must not be confounded with the essential oil, which is described in another section (see p. 1424). The fixed oil or butter is extracted from refuse nuts, by powdering, heating in a water-bath, and pressing while still hot. The yield is about 28 per cent. The fat is a solid unctuous substance, with an orange-act as a ferment, and render the oil rancid in course of time, besides holding in suspension a varying quantity of water. These impurities in the commercial oil are further increased by the fact that, when the oil is brought down to the coast, should no vessel be there prepared to receive it, it is frequently buried in the sand till an opportunity arrives for exporting it.

The following is the method of manufacturing the oil for internal consumption. The spadices are kept in a hot place for 3–4 days, and the nuts are then taken out. A small quantity (3–4 lb.) is made at a time. They are boiled in iron pots, then put into a wooden mortar, and pounded with wooden pestles. The pulpy mass is next mixed with tepid water with the hand. The chaff is first removed, and afterwards the stones. The oil remains mixed with the water, which is passed through a sieve (to remove the remaining chaff) into a pot placed on the fire, heated up to boiling-point, and allowed to continue in that state whilst the oil floats up as a bright-red substance. The water at this stage is being continually stirred, and the oil is removed as it floats up until the whole is collected. The oil is now put into a pot and heated, to drive out any water that may remain.

It has been estimated that the yield of oil from this palm is at the rate of 7 cwt. an acre, or more than $\frac{1}{3}$ greater than the oil product from the olive in S. Europe. On some parts of the W. coast of Africa where the regular collection of the fruits is not practised, the trees grow so thickly, and afford such regular and rapid crops, that the ground becomes covered with a thick deposit of the fatty matter afforded by the fallen nuts.

The oil obtained from the pericarp, the palm-oil proper, has the consistence of butter, a yellow colour, an odour resembling violets, and a mild flavour; it easily becomes rancid, bleaches in the sunlight, saponifies readily with alkali, dissolves in all proportions of ether, and in alcohol at 0·848 sp. gr. Its industrial applications are for the manufacture of candles and soap (see Candles; Soap); and the manufacture of tin-plate, in S. Wales and elsewhere. For this latter purpose, its non-drying qualities render it valuable as a preservative of the surfaces of the heated iron sheet from oxidation, until the moment of dipping into the bath of melted tin, the sheets being rapidly transferred to that from the hot oil bath, which consists almost entirely of palm-oil. The softest, purest, and most neutral oil is preferred for this purpose, and the kind known as "Lagos" is much used therefor. The exports of palm-oil from Lagos were 3,304,967 gal., value 239,133*l.*, in 1877, and 1,570,638 gal., 139,094*l.*, in 1878.

Until 10–12 years ago, palm-oil from certain parts of the African coast was usually mixed with the oil obtained in a very crude way from the kernel of the fruit (see Palm-nut-oil); as the kernels were somewhat burnt in the process of extraction, they communicated a peculiar smell to their oil, and that again to the palm-oil, which was known in the market as "coffee-oil," and, being difficult to bleach, and weaker in body, was considerably lower in price than good palm-oil. It is more usual now, however, for the kernels to be sent to England to be treated.

Scarcely any oil that finds its way into commerce has a greater range of quality than palm-oil. The various kinds are well known by the names of the parts of the coast whence they are shipped. The oil used to be brought home by small vessels trading from London, Liverpool, and Bristol, which went out with empty casks, and lay some months along the coast, especially near the mouths of rivers, until they were filled up with oil. The great regularity with which steamers now call at many African ports, and the cheapness of freight, has materially altered the mode of conducting the trade. Casks are now left at the various depots, and instead of, as formerly, a 300-ton ship coming home laden with one or two classes of oil, steamers arrive regularly in Liverpool with cargoes chiefly of palm-oil, made up at various ports of call, ranging perhaps from 8° N. and 13° W. (near Sierra Leone) to 10° S. and 12° E.

Along so great a range of coast, it is not a matter of surprise that there should be such variations in the quality of the oil, especially when, to differences in climate affecting the trees and their fruit are added differences in mode of preparation, &c. It is found, however, that the oil from any given port is tolerably uniform in quality. Thus, as explained before, Lagos oil, which chiefly comes to London, is the most neutral (i.e. non-rancid) and the cleanest, the water and other impurities not exceeding 1–2 per cent.; it is also nearly the softest. On the other hand, "Brass" oil is almost equally pure, but is the hardest of all the varieties, and contains the largest percentage of palmitic acid; hence it usually commands the highest price for candle-making in the Liverpool market. "Cameroons" and "Windward" oils (which chiefly come to Bristol) occupy an intermediate position as regards hardness; in the latter, impurities may amount to 5–6 per cent. "Saltpond" and "Monrovian" may be mentioned as instances of the most impure oils, 25 or even 30 per cent. being not an unusual amount of impurity. On this account, it has been proposed to sell palm-oil by analysis, guaranteed to contain —— per cent. of clean oil, just as soda-ash is sold at, say, 55 per cent. soda. The presence of these impurities tends to partially decompose the oil, and render it harder, since the fatty acids are more solid than the neutral fat whence they are derived. Any determinations, therefore, of the melting- or solidifying-points of palm-oil are utterly misleading. Commercial palm-oil itself is a mixture of palmitine and oleine (the glycerides), and of palmitic and oleic acids, in very varying proportions, with the addition of uncertain quantities of water, vegetable fibre, and sand.

Palm-nut-, Palm-kernel-, or Palm-nut-kernel-oil.—This oil, which is known in commerce under each of the synonyms given, is extracted from the nuts or kernels of the fruit described under Palm-oil. Some 10–12 years ago, the nuts were partly charred, and the oil that ran from them, discoloured by the burnt cellulose, was exported either separately or mixed with palm-oil. This brownish oil could only be very slightly bleached, and was therefore not of great value for soap-making. Since the improved methods of oil extraction (see p. 1451) have been worked out, the nuts have been exported to England, and the nearly colourless oil there extracted, while the ground nuts have been used for cattle-food. The following is a description of the old process, which is still in vogue in some districts.

The nuts which have been subjected to the processes described for making oil are deprived of their external pulp, and the kernels only remain; or old nuts are picked up from under the trees, and put in the sun for days, and even months, until they are perfectly dry. They are then broken between two stones, and the kernels are obtained whole, in perfect condition, and fit for exportation, and so form the commercial palm-kernels. If they have not been perfectly dried, the kernels break into pieces. The oil obtained from these kernels by the following process is called "white-kernel-oil." They are placed in wooden mortars, and pounded very finely; then removed to a grinding-stone, and ground into a homogeneous mass, which is put into cold water, and stirred with the hand. The oil rises in white lumps on the surface of the water, and is collected and boiled. It is of a very light straw-colour, and, when exposed to the sun and dew, becomes, after a time, perfectly white. "Brown" or "black" oil is thus obtained. The kernels are put into a pan, and fried; the oil oozes out, and is strained; the fried nuts are placed in wooden mortars, pounded, and afterwards finely ground on a grinding-stone. The mass is thrown into a small quantity of boiling water, and stirred constantly; the oil rises, and is continually skimmed off. The pulpy mass is removed from the fire, spread out in a large bowl, and allowed to cool, after which it is again ground, and put by until the cool of the day, when it is mixed with a little water to soften it. It is now beaten with the hand for some time until the oil comes out in white pellets. As soon as this is observed, a large quantity of water is put into it, and a fatty substance floats on the top; this is skimmed off and boiled, and the pure oil is obtained.

By whichever of these processes it is obtained, the oil, when freed from impurities, is of a pale primrose-yellow colour, with a characteristic odour not unlike that of coco-nut-oil, which it strongly resembles in its chemical and physical characteristics. Indeed, for soap-making, it has largely supplanted coco-nut-oil in the cheaper soaps in which that has hitherto been employed on a large scale. (See Coco-nut-oil; Soap.) It is slightly softer than good coco-nut-oil, its fusing-point being tolerably constant at 25½° (78° F.). If, however, the *whole* of the oil be removed from the kernels (by a suitable solvent), the resulting meal is not so fattening for cattle, but the oil is slightly harder, containing a larger proportion of the higher terms of the series, lauric (or lauro-stearic) acid, cocinic acid, &c. The oil itself, being tolerably pure, is a neutral glyceride, and does not readily get rancid. Its fatty acids, however, are partly fixed and partly volatile, like those of coco-nut-oil.

Phulwara-oil.—The *phulwara* or "Indian butter-tree" (*Bassia butyracea*) is a native of Nepal and the Almorah Hills, ranging between 1500 and 4500 ft. in elevation. The seeds or kernels, having the appearance of blanched almonds, are bruised to the consistence of a fine pulp, which is placed in cloth bags, and left under a moderate weight until the oil has escaped. The latter immediately assumes the consistence of hogs' lard, and remains in this semi-solid condition in the ordinary temperature of the plains of India, say 35° (95° F.), but melts completely at 49° (120° F.). It has a delicate white colour, keeps for many months in India without exhibiting any unpleasant flavour or odour, and is soluble in warm alcohol. Locally, it is extensively used as a medicinal application, as a perfumed ointment, and as an adulterant of *ghee* (clarified animal butter). It makes an excellent soap, burns in lamps with a bright flame free from smoke and smell, and is suitable for candle-manufacture. The refuse cake after extraction of the oil is eaten by the Indian poor. For oils yielded by other species of *Bassia*, see Illipi-butter (p. 1392), Mahwa-oil (p. 1394), and Shea-butter (p. 1410).

Pine-oils.—It is said that Prof. Guillemare has succeeded, by a very simple chemical process, in obtaining a lamp-oil, of unusual brightness and cheapness, from the resin of *Pinus maritima* (see Resinous Substances), which grows in great numbers on the S.-W. coast of France, and in Dalmatia. Pine oil is produced in Sweden by distilling refuse wood; 3 out of 15 factories there made over 3000 gal. in 1870. A similar product is obtained from *P. Abies*, in the Black Forest. Their sp. grs. vary from 0·926 to 0·931, and all have very low congealing-points, say below —25° (—14° F.). The quantity of oil extractable by carbon bisulphide from the seeds of various kinds of pine, fir, spruce, &c., varies from 11–12 per cent. in the hemlock-spruce, to 29 in the Swiss stone-pine and Weymouth pine.

Piney-tallow (Fr., *Suif de Piney*).—The seeds of *Vateria indica*, an Indian tree (see also

Resinous Substances—Piney-varnish), are cleaned, roasted, ground, and boiled in twice their bulk of water till the oil floats; the latter is removed, and the contents are stirred, and left till the following day, when more oil will have separated. It is a solid fat, melting at 35°–36° (95°–97° F.), of sp. gr. 0·926 at 15° (59° F.), white, greasy, and of agreeable odour; it makes excellent candles.

Piquia-oil.—The fruits of *Caryocar brasiliense*, a native of Guiana and Brazil, yield a sweet concrete oil, of brown colour, retaining much of the flavour of the fruit.

Pistachio-nut-oil (Fr., *Huile de Lentisque*).—An oil is extracted from the pistachio-nut (see p. 1359) on a small scale in Italy. The oil is greenish-coloured, sweet-flavoured, and aromatic; it is used in food, but soon becomes rancid, and is then applied to lighting purposes.

Plum-oils.—The kernels of the common plum (*Prunus domestica*) are pressed, in Wurtemberg, and made to yield a limpid illuminating-oil; its sp. gr. is 0·9127 at 15° (59° F.), and its congealing-point is −9° (16° F.); it soon becomes rancid. The apricot (*P. armeniaca*) gives an oil used in India for cooking, in lamps, and on the hair. The Briançon plum (*P. brigantiaca*) is similarly utilized in France, &c., by expressing the peeled kernels; the oil is well known under the name of *huile de marmotte*, and is largely used instead of, or as an adulterant of, almond- and olive-oils.

Poondy-oil.—The seeds of *Myristica malabarica*, a native of the forests of Malabar and Travancore, when bruised and boiled, yield a quantity of yellowish concrete oil, which, when melted down with a little bland oil, is applied efficaciously to ulcers.

Poppy-oils (Fr., *Huile d'Œillette, de Pavot*; Ger., *Mohnöl*).—Oil is yielded by the seeds of three kinds of poppy—the opium-poppy (*Papaver somniferum*), the spiny-poppy (*Argemone mexicana*), and the yellow-horn poppy (*Glaucium luteum*).

The cultivation of the first-named has been described at length under the head of Narcotics—Opium. In Asia Minor and Persia, after the collection of the opium from the poppy-heads (see p. 1309), the latter are gathered, and the seed is shaken out and preserved. It is black, brown, yellow, or white; some districts produce more white seed than others. The seed is pressed in wooden lever presses, to extract the oil, which is used by the peasants for culinary and illuminating purposes. Some of the seed is also sold to Smyrna merchants, who ship it to Marseilles, where it is employed in soap-making, and as a substitute for linseed-oil. The average yield of oil is 35–42 per cent., the white seed being considered the richest. Samsoon, in 1878, exported 454,820 *kilo.* of poppy-seed, value 5458*l.*, to France. The values of the exports of poppy-seed from Bushire in 1879 were 25,000 rupees (of 2*s.*) to England, and 17,000 to India. The same economy takes place in India, where the plant is also grown for the sake of its seed alone in some districts. In this latter case, the sowing takes place in March–April, about 2 lb. of seed being sown broadcast to one acre. The seed-vessels ripen in August; the heads are then cut off, sun-dried, sorted, and trodden out in bags, or threshed. The seed is immediately crushed and pressed, the yield of oil being in proportion to the freshness of the seed, and amounting to 14 oz. from 4 lb. under favourable conditions. The oil readily bleaches by exposure to the sun in shallow vessels, and is then transparent and almost tasteless. The natives use it very largely for cooking purposes, and as a lamp-oil. The cake is consumed as food by the poorer classes. The unpressed seed is largely exported from India, almost exclusively from Bengal; the shipments were 449,394 cwt. in 1878, and 249,072 in 1879. About $\frac{2}{3}$ of the total come to England, and $\frac{1}{3}$ goes to France. The latter country grows a large quantity of poppy-seed at home, over 100,000 acres in the N.-W. having been returned as under this crop some few years since. The French oil is of two kinds, a white cold-drawn oil, and a coarser oil obtained by a second expression and from inferior seed, the total yield being 40 per cent. The finer oil is fit for alimentary purposes, and is largely used to adulterate olive-oil; it is also employed as a lamp oil, and very extensively by artists for grinding light pigments, as, though possessing less strength and tenacity than linseed-oil, it keeps its colour better. The coarser kind is chiefly made into hard soaps in S. France, being used with other oils to the extent of about a quarter. The pure oil has a golden-yellow tint, and agreeable flavour; its sp. gr. is 0·924 at 15° (59° F.); it solidifies at −18° (0° F.), and remains long in this state at −2° (28½° F.); is slow to become rancid, and saponifies readily; dissolves in 25 parts cold and 6 parts boiling alcohol; and dries in the air more rapidly than linseed-oil.

Argemone mexicana, a native of Mexico, has become distributed all over the globe, and is found abundantly in waste places and in rubbish heaps, notably in the E. Indies and America. In Bengal, and more or less throughout India, the seeds are collected and expressed for their oil, which is yielded almost as plentifully as from mustard-seed. The drawn oil is twice allowed to stand for a few days to deposit a whitish matter, after which it remains clear and bright. It has a light-yellow colour, slightly nauseous odour, and raw flavour; it remains liquid at 5° (41° F.), dissolves in 5–6 volumes of alcohol at 0·818 sp. gr., and saponifies readily. It burns well, and has been recommended as a lubricator, besides being credited with medicinal virtues.

Glaucium luteum is a common plant on the sandy shores of the Mediterranean, the W. coast of Europe as far as Scandinavia, and some parts of N. America. It is very hardy, and cultivated with little trouble. It prefers stony and chalky soils, where few other plants will thrive, and has therefore been recommended for culture on such otherwise waste land. Under cultivation, it affords about 10 bush. of seed per acre. The seed contains 42½ per cent. of oil, and yields about 32 per cent. by pressure. The oil obtained by cold expression is devoid of odour and flavour, and has a sp. gr. of 0·913. It is applicable to culinary and illuminating purposes, as well as for soap-making and paint. The cake is a good phosphatic manure. It seems to have been very little utilized, probably on account of the comparatively small yield of seed.

The common red poppy (*Papaver Rhœas*) has been described under Dyestuffs (p. 864); in France, it is cultivated in Artois and Picardy, and the seeds are pressed on the spot for their oil, which is known as "white oil."

Pulza-, Seed-, or Purqueira-oil (Fr., *Huile de Médicinier, de Pignon d'Inde*).—The seeds of *Curcas purgans* (see Nuts—Physic-nut, p. 1359) yield a large quantity of oil, some 350,000 bush. of the seed being sent annually from the Cape Verdes to Portugal for expression. This operation is performed in the dry, on seeds slightly roasted and crushed; 1000 lb. of the seeds give 640 lb. of kernels, which yield 260 lb. of oil. The industry is carried on most extensively at Lisbon.

Safflower- or Curdee-oil.—The seeds of the safflower (see Dyestuffs, p. 865) afford about 20 per cent. of fatty oil. The plant is cultivated chiefly for the sake of its dye, but the abstraction of the petals for this purpose (see pp. 865–6) does not affect the yield of seed. There are two ways of extracting the oil from the seed:—(*a*) The seeds are freed from husks, crushed, and pressed, the product being about 25 per cent. of oil, of light colour, and good burning qualities. (*b*) An earthen jar is set in the ground, and covered with an earthen plate having a hole of about ¼ in. diameter in the centre; upon the plate, is inverted a second jar filled with the seed, the joints are carefully luted with clay, and earth is piled up to the shoulder of the inverted jar; dried cow-dung is then heaped around the upper jar, and kept burning for about ½ hour. On completion of the operation, the upper vessel will be ½ full of charred seed, and the lower ⅓ full of black sticky oil. The latter, extracted in this way, is valueless for burning, but esteemed by the natives above all others for preserving leathern vessels exposed to water, and the yield is ¼ more than by the press. The expressed oil is light-yellow and clear, and used locally for culinary and other purposes; it is also said to enter largely into the composition of the so-called "Macassar hair-oil." Its industrial qualities have been neglected in Europe.

Shea-, Galam-, or Bambouk-butter.—The *cé*, *shea*, or butter-tree of W. Africa (*Butyrospermum* [*Bassia*] *Parkii*) forms miles of forest on the S. bank of the Niger, and the same or an allied species, locally termed *lulu*, is common on the river Djour, in the Bahr el Ghazal province, where its "butter" is used by the natives in cooking. The seeds, as large as pigeons' eggs, are exposed for several days to dry in the sun, and reduced to flour in a mortar; the flour is placed in a vessel, sprinkled with warm water, and kneaded to the consistence of dough. When the kneading has proceeded so far that greasy particles are detached by the addition of hot water, this last operation is repeated until the fat is completely separated, and rises to the surface. The fat is then collected, and boiled over a strong fire, with constant skimming, to remove any remaining pulp. When sufficiently boiled, it is poured into a damp mould, and, when set, is wrapped in leaves, and will keep thus for two years. The yield is 30–40 per cent. The "butter" is white, with sometimes a reddish tinge, and may be rendered white by repeated filtration in a warm closet; it resembles tallow in appearance, but is more unctuous, and greases the fingers; it has a faint characteristic odour, and a sweetish flavour. Its melting-point is variously stated, from 23°–24° (73½°–75¼° F.) to 43° (109½° F.). According to one authority, the fatty acid is margaric, and its melting-point is 61° (142° F.); according to others, there are two fatty acids, stearic and oleic, the melting-point of the mixture being 69° (156° F.). Yet another authority states the proportions as 7 of stearine to 3 of oleine, and states that when acidified and distilled, it gives a yellow, crystalline fatty acid melting at 56° (133° F.), and when pressed, at 66° (151° F.), but that it cannot be used for candle-making, as it is soft, despite its high melting-point. It dissolves entirely in the cold in turpentine-spirit, incompletely in ether, and is almost insoluble in alcohol. It saponifies readily with alkalies. There is also present in it, in the proportion of ½–¾ per cent., a substance resembling guttapercha, and which has been called "guttashea" (see Resinous Substances). It is insoluble in alcohol, alcohol and ether mixed, acids, and alkalies; but slightly soluble in pure ether, and in ordinary animal and vegetable fats. It can be removed from the fat by dissolving in a mixture of 3 parts of ether and 1 of alcohol, when it separates in a filmy state, more readily if the fat be first saponified. It exists ready-formed in the oil, some in suspension, removable by filtration, some in solution in the fat. The fat itself, shea-butter, is imported to the extent of 300–500 tons annually, from Sierra Leone, for use in the manufacture of hard soaps, chiefly in combination with other oils. It is largely consumed in some of the Continental candle-factories. The natives employ it for food, for anointing, and for lighting. Other *Bassia*-oils are described under Illipi-butter (p. 1392), Mahwa-oil (p. 1394), and Phulwara-oil (p. 1408).

Simbolee-oil.—A clear, transparent oil is expressed from the seeds of the "curry-leaf" tree (*Bergera* [*Murraya*] *Kõnigii*), in Bengal and S. India.

Siringa-oil.—The seeds of *Hevea brasiliensis* [*Siphonia elastica*] (see Resinous Substances—Indiarubber) afford an oil which is useful for making hard soaps, and printing-ink.

Soap-nut-oil.—A semi-solid oil is obtained from the seeds of *Sapindus emarginatus* [*trifoliatus*] (see Nuts—Soap-nuts, p. 1360) in India, and is used medicinally. Another oil is procured from *S. Saponaria* in the W. Indies and N. Central America.

Sunflower-oil.—The sunflower (*Helianthus annuus*) has long been grown for its oil-seeds in Russia and India, and the cultivation has more recently been taken up in Germany and Italy. The plant grows readily in most soils, but prefers light, rich, calcareous land, unshaded by trees. In Russia, the seed is drilled into lines 18 in. apart, and the plants are thinned out to 30 in. apart in the rows, thus giving about 11,000 plants in an acre. The quantity of seed required for an acre is 4–6 lb., and the sowing takes place in September–October, the crop being ready to harvest in February. In England, it is recommended for any vacant ground, to be planted 6 in. apart and 1 in. deep, and to be earthed up when 1 ft. high, requiring no subsequent attention. The yield of seed is much increased by topping the plants, and the best manure is old mortar. Each plant produces about 1000 seeds, chiefly on the main head. Experimental culture in France gave a return of 1778 lb. of seed, yielding 15 per cent. of oil (275 lb.), and 80 per cent. of cake, from an acre; but the product varies considerably according to soil, climate, and cultivation, and the average may be roundly stated at 50 bush. of seed from an acre, and 1 gal. of oil from 1 bush. of seed. The percentage of oil to seed ranges from 16 to 28; and that of husk to kernel, from 41 to 60. The Italian cultivation is confined to the neighbourhoods of Piove and Conegliano, in Venetia. In Russia, the plant is most extensively grown in Kielce and Podolia, and the district of Birutch, in Voronej; the production of seed is now estimated at 8 million *poods* (of 36 lb.), from an area of 80,000 *dessatines* (of 13,067 sq. yd.) In Tartary and China, it is cultivated in immense quantities, but no actual statistics are available. In India (Mysore), 1 acre of land gives 11½ cwt. of seed, which yields 45 gal. of an oil which is there compared with ground-nut-oil, and applied to the same uses. The Russian seed is expressed on the spot, and the oil is largely employed for adulterating olive-oil. The purified oil is considered equal to olive- and almond-oil for table use. The chief industrial applications of the oil are for woollen-dressing, lighting, and candle and soap making: for the last-mentioned purpose, it is superior to most oils. It is pale-yellow in colour, thicker than hempseed-oil, of 0·926 sp. gr. at 15° (59° F.), dries slowly, becomes turbid at ordinary temperatures, and solidifies at −16° (4° F.). The cake is excellent food for cattle and poultry, and the stems yield a fibre (see Fibrous Substances—*Helianthus*, p. 961).

Tea-oil.—The seeds of the tea-plant, *Camellia Thea* [*Thea chinensis*] (see Tea), contain a considerable proportion of oil, as much as 1 cwt. being obtainable by industrial means from 3 cwt. of seed. The oil resembles that of the olive, burns with a clear, bright light, and is free from unpleasant odour. The general extraction of this oil is recommended to tea-planters. But there is every reason to believe that the "tea-oil" which figures largely in Chinese and Japanese commerce is not the product of the tea-plant, but of an allied species (*C. Sasanqua*, or *C. oleifera*). The Chinese assert that this plant is identical with the tea-plant, only cultivated differently; but they may have easily confounded the two plants, and additional confusion has arisen from the fact that the Japanese add *Camellia*-leaves to their tea, on account of their pleasant aroma. The *Camellia* is very largely cultivated in China, the shrubs being grown to a height of 8–9 ft. The seeds are crushed to a coarse powder, boiled, and pressed. The oil is employed locally for many domestic purposes, and is an important article of trade. Hankow exported 3640½ *piculs* (of 133⅓ lb.) in 1878, and 5826 *piculs*, value 11,442*l.*, in 1879; Shanghai, in 1879, imported 5792¼ *piculs*, and exported 2991½. Another species, *C. drupifera*, grows abundantly on the E. Himálaya, and under cultivation in Cochin China; in the latter country, its oil is used medicinally.

Tobacco-oil.—The seeds of the tobacco-plant (see Narcotics—Tobacco, p. 1325) contain about 30 per cent. of a fatty oil, which is extracted by powdering them, kneading them into a stiff paste with hot water, and pressing hot. The oil is clear, limpid, golden-yellow in colour, inodorous, and mild-flavoured; its density is 0·923 at 15° (59° F.); it remains liquid at − 15° (6° F.), dissolves in 168 parts of alcohol at 0·811 sp. gr., and saponifies readily. One authority excludes it from the drying oils; another considers its drying quality to be unusually developed, and recommends it for paints and varnishes.

Tucum-oil.—The fruit-pulp of the *tucum*, *aouara*, or *kiourou* (*Astrocaryum vulgare*), of Brazil and Guiana, yields an oil used for many different purposes. The palm is more important perhaps as a fibre-yielder (see Fibrous Substances—*Astrocaryum*, p. 920).

Tung-, Tree-, or Wood-oil.—This fatty oil is a product of the so-called "oil-tree" of China, Cochin China, and Japan (*Aleurites cordata* [*Elæococca vernicia, Dryandra cordata*]), and must not be confounded with the Malayan article, which is an oleo-resin (see Resinous Substances—Gurjun). The fruit capsules of the *t'ung* are filled with rich oil-yielding kernels, from which 35 per cent. by weight of oil may be obtained by simple pressure in the cold. The sp. gr. of the oil is 0·9362 at 15° (59° F.). It possesses several remarkable properties: heated to 100°–200° (212°–

392° F.) out of contact with the air, it retains its original limpidity after cooling, but in contact with the air, it solidifies almost instantaneously, melting again at 34° (93° F.), and exhibiting the same elementary composition; the cold-expressed oil rapidly solidifies by light in the absence of air; and its drying qualities exceed those of any other known oil. It is devoid of colour, odour, and flavour. The oil is produced in immense quantities in China; in the provinces of Ichang and Szechuen, it is one of the principal articles of native manufacture, and its importance in local commerce is shown by the following statistics:—Hankow, the chief market for the export trade, exported 336,053 *piculs* (of 133⅓ lb.) in 1878, and 203,820½ *piculs*, value 317,548*l.*, in 1879; Shanghai imported 69,223¾ *piculs*, and exported 31,492¾, in 1879; Chefoo imported 4011 *piculs* in 1878, and 2847 in 1879; Chinkiang imported 184,442 *piculs* in 1878, and 117,082 in 1879; Ningpo imported 29,652 *piculs* in 1878, and 13,915 in 1879; Wuhu imported 11,916½ *piculs* in 1878, and 6695 in 1879, in foreign craft, and, in the latter year, a quantity estimated at 3711 tons in native craft. In China, the oil is universally employed for caulking and painting junks and boats, and for varnishing and preserving woodwork of all kinds; also for lighting, though considered inferior to *Camellia*-oil (see Tea-oil) for this purpose, and in medicine. The oil is unknown to European commerce, but an attempt to naturalize the tree in Algeria has been projected. Its industrial value has been too long neglected.

Vegetable Tallow (Fr. *Suif d'arbre*).—At least two vegetable fatty substances are known by the name of "vegetable tallow."

(*a*) *Chinese.*—The vegetable tallow of China is produced by the "tallow-tree" (*Stillingia* [*Croton, Sapium, Excœcaria*] *sebifera*). It is a native of China and the adjacent islands, and has been introduced and naturalized in India and the warmer parts of America. In China, it is chiefly cultivated in the province of Chekiang, and the adjacent Chusan Archipelago, in Kiangse, and in Hoopih. In India, it thrives in the N.-W. Provinces and the Punjab, especially at Paonee, in Gurhwal; at Ayar Tali and Hawul Baugh, in Kumaon; and in the Kangra Valley. The tree flourishes equally well on low alluvial plains, in the rich mould of canals, in sandy soils, and on mountain slopes. Its fruits are about ½ in. in diameter, and contain 3 seeds, thickly coated with a fatty substance, whence the "tallow" is obtained. The ripe fruits are gathered at the commencement of the cold weather, November–December, when all the leaves have fallen, by means of a sharp crescent knife, attached to a long pole. The seeds are first picked from the stalks, and bruised in a mortar to loosen the shells, which are sifted away. The clean seeds in their fatty envelope are next placed in a wooden cylinder, open at the top, and with convex open wickerwork bottom, suspended within iron dishes 6–8 in. deep, containing water which is made to boil; the seeds are thus steamed for 10–15 minutes, when they are removed, and mashed in large mortars, and thence transferred to bamboo sieves, kept at a uniform temperature by means of live ashes. The tallow separates, and escapes through the sieves, forming a solid mass. (The seeds are usually passed through the steaming and straining processes a second time. Finally the seeds are themselves treated for their oil, as will be described presently.) The tallow now resembles coarse linseed meal, its brown colour arising from the thin skin between the seed and the tallow, which is separated by pounding and sifting. The tallow is next put between circles of twisted straw, 5–6 of which, laid upon each other, form a hollow cylinder, bound with bamboo hoops 3 in. wide. The straw cylinders when filled are placed in a rude press with their hoops attached. The tallow is forced out in a liquid state, and is collected in receptacles, where it solidifies on cooling. It is again melted, and poured into moulding-tubs, sprinkled inside with dried red earth, to prevent adhesion. When cold, it is turned out in masses of 80 lb., a hard, brittle, pure opaque white, tasteless and odourless fat. Its melting-point varies from 37° to 44° (98½°–111¼° F.), and its composition is almost pure stearine. The yield is about 20–30 per cent. of the weight of the seeds. Its chief and almost only application in China is for making candles, which are usually coated with wax; in India, it has been tried as a lubricator; and it is found to burn well, without smoke or smell. An immense native trade is carried on in it in China. Hankow exported 89,269 *piculs* (of 133⅓ lb.) in 1878, and 90,413½ *piculs*, 229,099*l.*, in 1879; Shanghai imported 46,611½ *piculs*, and exported 6003¼, in 1879; Chinkiang imported 44,987 *piculs* in 1878, and 42,943 in 1879; Ichang exported 843 *piculs*, 1119*l.*, in 1878, and 657½ *piculs*, 996*l.*, in 1879; Kiukiang exported 6207 *piculs*, 11,033*l.*, in 1878, and 4559 *piculs* in 1879; Wenchow exported 69 *piculs*, 416*l.*, in 1878, and 290¼ *piculs* in 1879; Wuhu imported 4814½ *piculs* in 1878, and 4287½ in 1879.

The oil previously alluded to as being obtained from the kernels of the seeds after removal of the tallow is extracted in the following manner:—The seeds are ground between mill-stones, which are heated to prevent clogging by the tallow still adhering. The mass is then winnowed, and the clean kernels are steamed, and mashed in a cumbrous edge-runner mill. The meal is steamed in tubs, made into cakes, and pressed, the whole course of operations being performed twice. The yield is about 30 per cent. of the cleaned kernels. The oil is used for varnishing umbrellas, anointing the hair, and medicinally; it burns well in lamps, but is inferior to some other oils in use for that purpose. The seed-husks and tallow-refuse are employed as fuel; the seed-cake forms a good manure, especially for tobacco.

(*b*) *Malayan.*—In Borneo, Java, and Sumatra, are several species of *Hopea*, producing nuts, which, when compressed, yield fatty oils, extensively used under the names of "vegetable tallow" and "vegetable wax." Three species of this genus are common in Sarawak; the one most valued for producing oil is a fine tree growing on the banks of the Sarawak river to a height of 40 ft.; its fruits are produced in the greatest profusion about December–January, and are as large as walnuts. These nuts are collected by the natives, and yield a very large proportion of oil, which, on being allowed to cool, takes the consistence of sperm, and in appearance very much resembles that substance. The natives at present only value this as a cooking oil; but when the demand for it in Europe becomes better known to them, they will doubtless increase their manufacture of it. In England, it has proved to be an excellent lubricator for steam machinery, far surpassing even olive-oil; and it has been used in Manilla in the manufacture of candles, and found to answer admirably. As it becomes more common, it will doubtless be applied to many other purposes. From the quickness of its growth, and the great profusion with which it bears its fruit, it will, should the demand for it continue, become a profitable object for cultivation, by which the quality and quantity would most likely be improved and increased. It is also found in Java and Sumatra. In Borneo, some 10 species are recognized by the natives, their nuts varying much in size. The kernels are covered with a hard shell, to separate which it is necessary to immerse them in water for 3–4 days. After the separation, they are exposed to the sun for about the same number of days, until the oil begins to exude; they are then pounded in a mortar, and boiled in water for some time; after which, the oil is expressed while hot. This oil has nearly the consistence, and something of the appearance, of tallow, but is generally yellower. It is found in the markets in rolls 1½–3 in. in diameter. It is used in the interior almost exclusively for lighting and culinary purposes. A vegetable tallow is also afforded by the seeds of *Tetranthera laurifolia*, widely dispersed over Tropical Asia, and the E. Archipelago, as far south as New Guinea. In Java and Cochin China, it is commonly used for making candles, notwithstanding its disagreeable odour. The exports of vegetable tallow from the state of Sarawak in 1879 were valued at 7305 dollars (of 4*s.* 2*d.*).

Both Chinese and Malayan kinds of vegetable tallow, like shea-butter, are glycerides, and contain about 95 per cent. of saponifiable matter, which has much less oleine in it than animal tallow.

(*c*) *African.*—A so-called vegetable tallow or butter is obtained in Sierra Leone from *Pentadesma butyracea*; the tree yields from its several parts, especially the fruit when cut, a yellow fatty juice. The fat of a species of *Pentadesma*, under the name of *kanya*, is used for culinary purposes in the neighbourhood of Zanzibar, and is said to remain sweet for a long time.

Walnut-oil (Fr., *Huile de Noix*).—The albuminous kernel of the walnut (see Nuts, p. 1360) affords some 50 per cent. of oil. It is said that it furnishes one-third of all the oil made in France; it is extensively prepared in the central and southern departments, notably Charente, Charente-Inférieure, and Dordogne, where it is commonly met with in barrels of 50 *kilo.* In both Spain and Italy, outside the olive-region, walnut-oil is largely expressed. It is of considerable importance in the hill districts of India, but is seldom seen in the plains. Cashmere and Circassia also include it among their industrial products.

The oil should not be extracted from the nuts until 2–3 months after they have been gathered. This delay is absolutely necessary to secure an abundant yield, as the fresh kernel contains only a sort of emulsive milk, and the oil continues to form after the harvest has taken place; if too long a period elapse, the oil will be less sweet, and perhaps even rancid. The kernels are carefully freed from shell and skin, and crushed into a paste, which is put into bags, and submitted to a press; the first oil which escapes is termed "virgin," and is reserved for feeding purposes. The cake is then rubbed down in boiling water, and pressed anew; the second oil, called "fire-drawn," is applied to industrial uses. The exhausted cake forms good cattle-food.

The virgin oil, recently extracted, is fluid, almost colourless, with a feeble odour, and not disagreeable flavour. Its sp. gr. is 0·926 at 15° (59° F.), and 0·871 at 94° (201¼° F.); it thickens to a butter-like consistence at −15° (5° F.), and solidifies to a white mass at −27½° (−17½° F.). In the fresh state, it is largely used in Nassau, Switzerland, and other countries, as a substitute for olive-oil in salads, &c., but is scarcely to be considered as a first-class alimentary oil. The fire-drawn oil is greenish, caustic, and siccative, surpassing linseed-oil in the last respect, and exhibiting the property more strongly as it becomes more rancid. On this account, it is preferred by many artists before all other oils. It affords a brilliant light; and may be used in the manufacture of soft-soaps.

Zachun-oil.—The seeds of *Balanites œgyptiaca*, of India, Egypt, Senegambia, and W. Coast Africa, afford an oil called *zachun* by the negroes.

Miscellaneous and Unenumerated.—The exports of unenumerated seed-oil from Holland were 18,787,000 *kilo.* in 1879. Dantzig exported 11,350 tons of oil-seeds, value 124,850*l.*, in 1879, chiefly to Holland and France. Russia exported 916,172 *chetverts* (of 5¾ bush.) of seed-oil in 1878. Venice exported 16,801 tons, value 765,194*l.*, of oil, and 3944 tons, value 79,114*l.*, of oil-seeds, in 1879.

In addition to the oils already specified in the preceding pages, the following plants are recorded as being capable of affording oil, the oleaginous part being the seed, unless otherwise specified:—

Acrocomia sclerocarpa, all over S. America.

Adenanthera pavonina, S. India, Bengal, and Burmah.

Allium sp. div., India; clear, pale, limpid, with strong garlic odour; used medicinally.

Amoora Rohituka, India and Ceylon; oil has many economic uses in Bengal.

Anda Gomesii, Brazil; medicinal.

Apeiba Tibourbou, Brazil, Venezuela, &c.

Arctium Lappa, the burdock, growing wild over Europe and Asia, gives 20 per cent. of oil.

Aspidium Filix mas (male-fern); obtained by treating the ether-extract of the tubers with water containing ammonia, and evaporating; thick, grass-green, liquid much below 0° (32° F.), used medicinally. (See Drugs, p. 811).

Astrocaryum acaule, Brazil.

Atropa Belladonna (see Drugs—Belladonna, p. 794); oil extracted in Wurtemburg, used for lighting and food; limpid, inodorous, sp. gr. 0·925 at 5° (41° F.), thickens at −16° (4° F.), and solidifies at −27½° (−19° F.).

Attalea Cohune, Honduras and Guiana, from the fruits, "Cohune-nuts."

Ballota nigra (black stinking horehound), proposed for cultivation in Savoy.

Bauhinia candida, India.

Bombax sp. div., India generally.

Bryonia callosa, India; extracted by boiling in water; a lamp-oil.

Carduus pycnocephalus, S. Europe and Réunion.

Celastrus sp. div., India, Brazil, &c.; deep-scarlet oils, used for burning in lamps, and medicinally.

Cerbera sp. div., E. and W. Indies, and S. America; *C. Manghas* [*Odollam*], oil used by Burmese and in India for lamps and anointing; *C. Thevetia*, "exile oil," naturalized in India.

Chironia scabrida, E. Indies.

Chrysobalanus Icaco, the *icaco* of Tropical America, and *ouaraye* of Senegal.

Cochlospermum Gossypium, India.

Connarus sp. div., India and Tropical S. America; sweet oil.

Cornus mascula (cornelian cherry), Europe and N. Asia.

Couepia dulcis, French Guiana.

Coula edulis, abundant on the Gaboon, is said to afford 53 per cent. of edible oil from its fruits.

Cynometra sp. div., India; wholly medicinal.

Cyperus esculentus; expressed from the tubers; yellow, mild, inodorous, sp. gr. 0·919, solidifies at 0° (32° F.), and saponifies readily.

Daphne Mezereum; by expressing the fruits; yellowish, drying oil, sp. gr. 0·8903 at 15° (59° F.), liquid at −16° (4° F.); contains 90 per cent. linoleine and oleine, and 10 per cent. stearine, palmitine and myristine.

Eriodendron anfractuosum, India, Cuba, &c.; clear, dark-brown.

Euphorbia Lathyris, France, Germany, and Switzerland, on the edges of fields and cultivated spots; 40 per cent. of a fluid oil, formerly used in medicine. *E. dracunculoides*, in India (*jy-chee*); 25 per cent. of the mature, husked seed; a drying oil equal to linseed-oil, but more fluid, does not become ropy with age, and emits scarcely any smoke while burning.

Feronia elephantum, India, Java, &c.

Fevillea sp. div., Brazil, Venezuela, and Tropical America generally; *F. cordifolia*, the *sequa*, affords a large quantity of semi-solid oil by pressing and boiling; the *abilla*-seeds of an allied Peruvian species contain so much oil that they are burnt as candles, and withstand considerable wind.

Heritiera sp. div., coasts of India, Africa, E. Archipelago, and cultivated in W. Indies.

Hesperis matronalis (dames' violet), Europe; greenish to brownish, sp. gr. 0·928, odourless, dries readily, quite liquid at −15° (5° F.).

Hura crepitans, W. Indies and India; a clear, pale, fluid, medicinal oil.

Hyoscyamus niger (see Drugs—Henbane, p. 812); pale green-yellow, thin, mild, inodorous, sp. gr. 0·913, scarcely soluble in 60 parts absolute alcohol.

Illicium anisatum (see Spices—Aniseed); a large quantity of fixed oil. (See also p. 1417.)

Impatiens sp. div., India, Europe, and N. America; for comestible and illuminating purposes.

Jatropha glauca, E. Indies; the seeds are collected when the capsules begin to split, and darken in colour; the fruits are placed between mats in the sun for a few hours to separate the seeds and husks, and the former are crushed and expressed; oil is fluid and light straw-coloured; used medicinally.

Kokoona zeylanica, Ceylon and the W. Peninsula; a lamp-oil.

Lactuca sativa (lettuce), India; clear, transparent and sweet.

Lecythis ollaria (see Nuts—Sapucaya, p. 1359).

Lepidium sativum (cress); brown-yellow, sp. gr. 0·924, thick and turbid at −6° (21° F.), solid at −15° (5° F.), dries slowly.

Litsœa [*Cylicodaphne*] *sp.*, Punjab, Himálaya, Java, &c.; the fruits of one tree give enough fat for 500 candles.

Livistona sinensis, N. Central America.

Lucuma mammosa, W. Indies.

Maclura aurantica (Osage orange); abundant, bland, limpid, resembling olive-oil, and burning with a steady flame.

Manicaria saccifera, French Guiana.

Mauritia flexuosa and *M. vinifera*, Brazil.

Mesua ferrea, the *nagkassar* of India, and in Java; dark, thick, and freely deposits stearine; used in lamps, and medicinally.

Mimusops sp. div. (see Timber), India, Ceylon, and the Archipelago; yielded abundantly; used medicinally and by painters.

Monodora grandiflora, E. and W. Tropical Africa.

Myristica angolensis, the *combo* of Gaboon, 72 per cent.; *M. longifolia*, E. Indies, 54½ per cent.

Nigella sativa (see Spices—Cumin), cultivated in Belgium, Egypt, and India; oil dark-coloured and fragrant.

Ocimum basilicum, E. Indies, Java, &c.

Oreodoxa [*Areca*] *oleracea* and *O. regia*, Réunion and Guadeloupe.

Pachira aquatica, Guiana and the Antilles.

Pangium edule, E. Archipelago, yield a fatty oil by expression.

Parkia biglandulosa, E. Indies, 18 per cent.

Paulownia imperialis [*Bignonia tomentosa*]; the *toï*-oil of Japan.

Pekea ternatea, Antilles.

Perilla ocimoides, Japan, used for making water-proof papers.

Persea gratissima (alligator pear), Tropical America, W. Indies and India; an abundant oil for illuminating and soap-making may be expressed from the fruit-pulp.

Pithecolobium dulce (Manilla tamarind), Mexico, Philippines, and India; light-coloured oil, with consistence of castor-oil.

Polanisia [*Cleome*] *viscosa*, Tropical India, Java, &c.; 9 per cent.; light olive-green, very liquid.

Prinsepia utilis, India; an edible and illuminating oil.

Putranjiva Roxburghii [*Nageia Putranjiva*], Central and Peninsular India; oil is olive-brown, and soon deposits solid portion; used for burning.

Raphanus sativus (radish), India; resembles colza, and has the same uses.

Reseda luteola (see Dyestuffs—Weld, p. 868), dark-green, thin, nauseous odour and flavour, sp. gr. 0·935, dries rapidly, liquid at −15° (5° F.).

Rottlera tinctoria [*Mallotus philippinensis*] (see Dyestuffs—Kamala, p. 861), E. Indies, *polongo*- or *kalapa*-oil; clear, limpid, sherry-coloured; used medicinally.

Salvia Chio, Guatemala; a drying oil, superior to linseed.

Schleichera trijuga, Indian Peninsula, Ceylon, and Burma; a lamp-oil. (See also Timber).

Sterculia fœtida, India, Ceylon, Java, &c.; extracted by boiling in water; semi-solid, deposits much stearine, becomes rancid within 10 days; 15 per cent.

Symplocos cratœgioides, Indus to Assam.

Tamarindus indica, E. and W. Indies; clear, bright, and fluid; gives a good light, without smoke or smell.

Telfairia pedata, Mauritius and Zanzibar, preferring light soil near water; each fruit contains 200–300 seeds, giving a nett weight of 50 lb., which yield 8 lb. of excellent bland oil; edible.

Thespesia populnea, most E. tropical countries, W. Africa, W. Indies, S. America, and Pacific Islands; deep-red, thick oil, used medicinally.

Thlaspi sp. div., proposed in France; 20 per cent.

Tilia parviflora, 30–40 per cent. by carbon bisulphide.

Trichilia capitata, Zambesi, large quantity of solid fat; also *T. emetica*, the *roka* of the Arabs.

Trigonella fœnum-grœcum, 6 per cent., fœtid, bitter.

Vernonia anthelmintica, S. India; solid, greenish; used medicinally.

Wrightia antidysenterica, E. Indies, medicinal.

Ximenea sp. div., W. Africa; 70 per cent., good for soap-making.

Zea Mays (maize); limpid, yellowish; burns well, and is a good lubricator.

VEGETABLE OILS [*B. VOLATILE AND ESSENTIAL*].

Acorn-oil.—The fruits of *Quercus robur* (see Timber—Oak), when distilled with water, yield an essential oil of buttery consistence, and peculiar, strong odour.

Albahaca-oil.—The *Myroxylon peruiferum* (see Resinous Substances—Tolu balsam) affords an essential oil of sp. gr. 0·892 at 13° (55½° F.), with a pleasant, aromatic, sassafras-odour.

Allspice- or Pimento-oil.—Both the fruit and leaves of several kinds of allspice or pimento (see Spices—Pimento) afford essential oil. The oil is most commonly extracted from the fruits. These, dried before they are quite ripe, are ground, and distilled with water. The product amounts to about 3–4½ per cent., rarely almost 6 per cent.; analysis reveals the presence of 10 per cent. in the husks, and 5 per cent. in the kernels. The yield of oil from the leaves has not been ascertained, but it is said to be considerable, and that the leaves and young shoots, destroyed while gathering the crop of berries, would repay distillation. The oil has a sp. gr. of 1·037, and very closely resembles clove-oil. It is frequently used as a substitute for or adulterant of the latter, both in medicine, and in combination with other oils for scenting soap. The small yield of oil renders it incapable of competition with clove-oil (p. 1420), except as a substitute.

Almond-oil.—An essential oil known as "bitter-almond-oil" is obtained from the bitter almond (see Fruit—Almonds, p. 1022), which also yields a fatty oil, described on p. 1377. Though bitter almonds are the only commercial source of the oil, it is also afforded by many plants of the *Pruneæ* and *Pomeæ* tribes, by a species of *Vicia*, and probably some others. It does not exist ready-formed, but is a product of the decomposition of amygdaline in the presence of water and emulsine. The process is as follows. The unpeeled almond-kernels are first pressed to extract their fatty oil (p. 1377); the residual cake is then placed in salt water for about 24 hours, prior to distillation. Without due precaution, there is some difficulty in the distillation, owing to the presence of much albuminous matter. Pettenkofer avoids this by immersing 12 parts of powdered almonds in boiling water, by which the albuminous matters are coagulated, and the amygdaline is dissolved. The addition of an emulsion of only 1 part of either sweet or bitter almonds will then suffice to effect the decomposition at a temperature not exceeding 40° (104° F.). The yield by this process from small quantities will sometimes reach 0·9 per cent. Some manufacturers force steam through the cake enclosed in coarse sacking. In dealing with large quantities of cake, the yield of essential oil varies widely; the yearly average may fall to 0·74 per cent., or rise to 1·67 per cent., which, reckoning 57 lb. of cake to represent 100 lb. of almonds, means 0·42–0·95 per cent. on the latter. This fluctuation is due partly to the want of uniformity in the bitter almonds used, and partly to the admixture of sweet almonds. The action of the emulsine on the amygdaline in the presence of water is very rapid, 200 lb. of cake being completely exhausted by a 3-hours' distillation. The crude oil contains a proportion of hydrocyanic (prussic) acid, feebly combined, and which is gradually set free. This crude oil is employed by perfumers; but the oil for medicinal use is sometimes deprived of the hydrocyanic acid by a process of purification. Maclagan's process consists in shaking up with lime and sulphate of iron (ferrous), and redistilling; the loss is 10 per cent. The purified oil is very liable to oxidize, unless carefully freed from water by agitation with fused chloride of lime. The oil is colourless and thin, of peculiar odour, and burning aromatic flavour; its sp. gr. is 1·061–1·065 when crude, and 1·049 when purified; its boiling-point is 180° (356° F.); it dissolves in 300 parts of water, and readily in alcohol and ether; by exposure to the air, it is oxidized, and converted into benzoic acid.

An "artificial oil of bitter almonds," or "essence of mirbane," is prepared by the action of nitric acid on benzol (see Coal-tar Products, pp. 654–5). They may be distinguished by treating with an alcoholic solution of potash: the natural oil is converted into a benzoate of potash; the artificial becomes a resin insoluble in alcohol and in ether.

Aloes-oil.—A pale-yellow, mobile oil, sp. gr. 0·863, boiling at 266°–271° (511°–528° F.), is afforded to the extent of 2 fl. dr. from 500 lb. of aloes (see Drugs, pp. 791–3).

Amber-oil.—A volatile oil is obtained from amber (see Resinous Substances), as a residue in the preparation of succinic acid, in the proportion of about 6 oz. from 6 lb. The crude oil is thick and greenish-brown, with a characteristic, disagreeable, bituminous odour, caustic acrid flavour, and sp. gr. 0·922 at 15° (59½° F.). It is used in perfumery.

Angelica-oil.—The root of *Archangelica officinalis* (see Angelica, p. 334), by aqueous distillation, yields much essential oil (about 1 lb. from 150–200 lb. of root), with a penetrating odour, and flavour of the root.

Angostura-oil.—Angostura-bark (see Drugs—Angostura, p. 793), when distilled with water, affords about 0·75 per cent. of a pale-yellow oil, of peculiarly aromatic odour, mild and afterwards acrid flavour, sp. gr., 0·934, boiling at 266° (511° F.).

Aniseed-oil.—Essential oils are obtained by distillation from the fruits of *Pimpinella Anisum* (see Spices—Aniseed), and from the roots of *P. nigra* [*Saxifraga*]. The first-named is slightly yellowish, possessing in a high degree the odour and flavour of the fruits; its sp. gr. is 0·977–0·983; it solidifies at 10°–15° (50–59° F.) to a hard crystalline mass, and resumes fluidity at about 17° (62½° F.); dissolves readily in alcohol. The yield obtained is about 3 per cent. of oil from the best Moravian seed, 2·5–2·7 from Russian, and 2·3 from German. The oil from the root of *P. nigra* has a light-blue colour; it does not appear to be an article of commerce. Aniseed-oil is administered medicinally to both men and cattle; it is largely employed in the preparation of cordials, especially in Latin Europe and S. America; and is suitable for scenting soaps and pomatums. It is often adulterated with spermaceti and fennel-oil stearoptene, and with cheaper essential oils. It cannot be scientifically distinguished from star-anise-oil.

Anise- [Star-] oil.—The fruits of the star-anise or Chinese anise, *Illicium anisatum* (see Spices—Aniseed), distilled with water, furnish 4–5 per cent. of essential oil, identical in all chemical respects with that of aniseed, but possessing a slightly different flavour. It is used for the same purposes as aniseed-oil, and very commonly mixed with or substituted for it. The fruits are chiefly distilled in Europe, but China exports considerable quantities of the oil itself. Thus the shipments from Pakhoi which paid duty in 1879 were 800 *piculs* (of 133⅓ lb.), and the recorded value was 15,134*l.*; from Macao, an annual export takes place to Europe and New York, and an occasional one to Manilla, the figures in 1878 amounting to 470 *piculs*, at a price fluctuating between 180 and 325 dollars (of 4*s.*).

Asafœtida-oil.—Asafœtida (see Resinous Substances), distilled with water, gives a yellowish oil, of strong garlic odour, soluble in water, and readily in alcohol, boiling at 130°–140° (266°–284° F.).

Avens-oil.—The root of *Geum urbanum*, distilled with water, gives a greenish-yellow oil, of buttery consistence, and clove-like odour.

Balm-oil.—The oil or otto of balm, or of melissa, is obtained by aqueous distillation of the whole herb, *Melissa officinalis.* The plant is cultivated in England, and grows wild commonly in S. France. The oil is pale-yellow, thin, of pleasant, lemon-like odour, and sp. gr. 0·85–0·92. It is an esteemed perfume.

Moldavian balm (*Dracocephalum moldavicum*) yields about ⅛ per cent. of a strongly aromatic and very agreeable essential oil. The plant is cultivated in S. France, but its product is hardly known in commerce.

Bay-oil. See Laurel-oils, pp. 1422–3.

Bayberry-oil.—The leaves of *Myrcia acris* afford a volatile oil, which is often called "bay-oil" or "oil of bay-leaves," but more correctly "bay-berry oil," being quite distinct from the bay or laurel (see pp. 1422–3). The leaves are largely received from the island of St. Thomas (W. Indies), and distilled in America. A 200-gal. copper still, heated by either wet or dry steam, takes 200–300 lb. of the leaves at a charge, and works them off in 8–12 hours, giving 80–100 gal. of distillate. The oil comes over in two portions:—(1) light oil, sp. gr. 0·870–0·990; and (2) heavy oil, sp. gr. 1·023–1·037. The freshly-distilled oil has a rank odour, but after keeping for 3–6 months, it mellows, and has the characteristic fragrance of the best "bay rum."

Benzoin-oil.—The natives of the E. Archipelago distil a volatile oil from gum benzoin (see Resinous Substances), by heating it in an earthenware pot, tightly covered, and providing a small bamboo for the escape of the oil. Various inert substances are placed in the retort with the gum, but no water. The oil is highly valued locally as a perfume for the hair.

Bergamot-oil.—The oil or essence of bergamot is procured from the fruit-rind of *Citrus Bergamia*, a member of the orange family (see Fruit, p. 1025). The tree is cultivated at Reggio, in Calabria, and in Algeria, and is unknown in a wild state; it occupies low ground, near the sea. The soil is well irrigated, and cropped with vegetables, and lemon- and orange-trees are often interspersed among the bergamot-trees. The smooth, thin peel abounds in a peculiarly fragrant essential oil, which is obtained from the full-grown but immature (green) fruits, gathered in November–December. The oil was formerly extracted by distillation, or by expressing the rasped rind; but these processes have been superseded by the *écuelle*, a special instrument described in a separate section (see p. 1457). By this, about 7000 fruits can be treated in a day, the yield of oil being 2½–3 oz. from 100 fruits. It is much greener than that extracted by the older processes. During some weeks after extraction, it gradually deposits much greasy matter, termed "bergaptene," or "bergamot-camphor," which, after exhaustion by pressure, is distilled with water to recover the final portions of oil it contains. The fruits which have yielded their oil are subjected to expression, and the juice is concentrated and sold for making citric acid (see Acids, p. 48), while the ultimate residue is consumed by cattle. The oil is thin, mobile, of very fragrant odour bitterish flavour, slightly acid reaction, pale greenish-yellow colour (due to chlorophyll), and sp. gr. 0·86–0·88; its boiling-point ranges between 183° and 195° (361½°–383° F.); it dissolves clearly ½ part of carbon bisulphide, and is inappreciably soluble in that body. It is never free from adulteration, either with oil distilled from the leaves or residual fruits, or with lemon-oil, or turpentine-oil, or even petroleum. It is shipped principally from Messina and Palermo, in bottles similar to those containing lemon-oil. It is extensively employed in perfumery.

Birch-oils.—An essential oil is extracted from the bark of the common birch (*Betula alba*), and another from its leaves. The tree or shrub inhabits high N. latitudes in Europe and Asia, being more common than any other tree throughout the Russian empire, and found in every wood and grove from the Baltic to the Eastern Ocean. It is numerous in Scandinavia, less so in Scotland, Iceland, and Greenland, and forms little woods at 6000 ft. in Italy. The extraction of birch-bark-oil is an industry of some importance in N. Europe and Siberia, and is conducted in the following manner:—An iron pot is filled up with bark, and covered with a close-fitting lid, through which is inserted an iron pipe. On this, is inverted a similar pot, and the rims are carefully fitted together, and well luted with clay. The two are then turned upside down, so that the pot with the bark in it is uppermost. The apparatus is half sunken in the ground, well banked up with a mixture of sand and clay, and a wood fire is kindled round it. When the distillation has continued long enough, the luting is removed, and the pots are separated, when the lower one is found to contain a thin oil floating on pyroligneous acid, or, when the bark has been very impure, on pitch. The yield of pure birch-bark-oil is about one-third by weight of the white bark used. To obtain a *centner* (120 lb.) of oil, 10–14 trees of 30–50 years old have to be stripped. Now that the value of standing trees is becoming better understood in Russia, the trees are not felled, as was formerly the custom, but, in many districts, are stripped standing, and left to grow on. In such cases, the outermost bark alone is removed, and that but partially. The underlayers blacken and die, but new bark is formed beneath them, and the growth of the tree continues. The oil should be kept in well-closed vessels, as it is somewhat volatile. It can be refined by boiling over charcoal, and filtering, when it becomes as limpid as linseed-oil, and can be used for similar purposes.

Recently the preparation of this oil has been carried on in Germany and Austria, where it is known as *Birkentheer*, *Birkenöl*, *Juchtenöl*, or *Döggut*. This oil is used almost exclusively in the preparation of Russia-leather (see Leather, p. 1236), to which it communicates a peculiar fragrance. The bark is also a valuable tanning material (see Tannin—Birch-bark).

The essential oil obtained by distilling the leaves of the birch with water is colourless, thin, of pleasant balsamic odour, a mild, sweetish, and afterwards peculiarly balsamic, acrid, and hot flavour; it becomes turbid at 0° (32° F.), but is not hard or crystalline even at −10° (14° F.); and is soluble in 8 parts of alcohol at 0·850 sp. gr.

Cajuput-oil.—A medicinal oil of some importance (see Drugs—Cajuput, p. 795) is obtained from the leaves of the *kayu-puti* or "white-wood tree" (*Melaleuca minor* [*Leucadendron Cajuputi*]). It is widely spread and abundant in the Indian Archipelago and Malayan Peninsula, and is also found in N. Australia, Queensland, and New South Wales. There are many varieties of it, and that grown in the island of Bouro, eastward of Celebes, is said to yield the best oil. The leaves somewhat resemble those of the common willow. They are plucked by hand, placed in baskets, and carried to sheds, where they are emptied into the stills. These are of the usual Malayan form. The leaves and water to be distilled are contained in a cast-iron circular rice-pan, around the margin of which is placed a roll of cloth, forming a tight joint for the reception of the condenser that fits down upon the pan. This condenser consists of a wooden tub without ends, into the top of which is dropped a conical copper tray, kept supplied with cold water; the products of evaporation condense upon the lower surface of the tray, and converging to its apex, fall into a spoon-shaped spout, which conveys them through a hole in the side of the tub to a receptacle. About 8000 bottles annually are produced in Bouro, valued at about 1 *guilder* (1*s.* 8*d.*) each. It forms almost the only export of this island. The receipts at Singapore in 1871 were:—3895 gal. from Celebes, 445 from Java, 200 from Manilla, and 350 from other places; total, 4890 gal. Of this, the greater portion was re-exported to Bombay, Calcutta, and Cochin China. The oil arrives here from Singapore and Batavia in common beer- and wine-bottles. It is a transparent mobile fluid, of light bluish-green colour (due to presence of copper, but rarely if ever in dangerous quantity), fragrant camphoraceous odour, and bitterish aromatic flavour; its sp. gr. is 0·926; it remains liquid even at − 13° (8½° F.), and boils at 175° (347° F.); and dissolves readily in alcohol.

Very similar oils are derived from other species of *Melaleuca*. That of *M. ericifolia* is pale-yellow, sp. gr. 0·899–0·902; *M. Wilsonii*, sp. gr. 0·925; *M. parviflora*, amber-coloured, sp. gr. 0·938; *M. uncinata*, peppermint-odour; *M. genistifolia*, pale greenish-yellow; *M. squarrosa*, green colour, disagreeable flavour; *M. linariifolia*, light straw-coloured, pleasant odour and flavour, sp. gr. 0·903. The plant called *kayu-glum* by the natives grows very extensively on the Malay Peninsula, and produces a similar oil to *kayu-puti*, but darker in colour. Fisher has distilled considerable quantities of it, and states it to be in wide medicinal use in the East.

Camphor-oils.—See Camphor, p. 578.

Caraway-oil.—A valued essential oil is obtained from the seeds of *Carum Carvi* (see Spices—Caraway). Distillation is performed with water, and without previous comminution of the seeds. Dutch seed yields about 5½ per cent. of oil; German, 7 per cent.; and Norwegian, 5·8 per cent. In England, preference is given to oil distilled from home-grown seed; on the Continent, the oils from the caraways of Halle and Holland are esteemed finer than those procured in S. Germany. An inferior oil is extracted from the refuse of the fruit, being mixed with turpentine-oil before distilling. The oil is colourless or pale-yellow, thin, with strong odour and flavour of the fruit; its sp. gr. is 0·91–0·97. It consists of about ⅓ carvene, boiling at 173° (343½° F.), and having a sp. gr. of 0·861 at 15° (59° F.). Carvol, the odoriferous portion, boils at 224° (435° F.), and has a sp. gr. of 0·953 at 20° (68° F.). Caraway-oil is employed in medicine, but more largely as a scent for soaps.

Cardamom-oil.—The parenchyma of the albumen and the embryo of cardamoms (see Spices—Cardamoms) contain a varying percentage of essential oil, amounting to 5 in Madras cardamoms, and 3·5 in Ceylon. It is extracted by aqueous distillation. It is pale-yellow in colour, with the odour and flavour of the seeds; sp. gr. 0·92–0·94.

Cascarilla-oil.—The bark of *Croton Eluteria* (see Drugs—Cascarilla, p. 797), distilled with water, affords about 1·1 per cent. of essential oil, which is rarely extracted, the bark itself being used by perfumers. The oil is dark-yellow, with an odour of camphor, lemons, and thyme, an aromatic, bitter flavour, sp. gr. 0·938, and commencing to boil at 180° (356° F.).

Cedar-oil.—From the pencil-makers' shavings of American cedar (*Juniperus virginiana*), is extracted an essential oil, in the proportion of about 28 oz. from 1 cwt. of the shavings. The true Lebanon cedar (*Cedrus Libani*) affords an oil of very indifferent odour. Cedar-oil is a soft, white, crystalline mass, of peculiar aromatic odour, solidifying at 27° (80½° F.) after desiccation, and distilling below 282° (539° F.). It is extensively used for scenting soaps, and is generally employed in America in lieu of savin-oil, being often called "N. American savin."

Cedrat-essence or Citron-oil.—From the rind of the scarcely ripe fruit of the citron (see Fruit, p. 1023) is obtained an essential oil, either by distillation or expression, much esteemed in perfumery. It is thin, colourless, or yellowish, of pleasant lemon odour, sp. gr. 0·840–0·860, boiling at 160°–175° (320°–347° F.). It is prepared in small quantity, and much of that sold under the name is fictitious, as the rind is in great demand for "candying" (see Food Preservation, p. 1018).

Celery-oil.—By the aqueous distillation of the herb and fruits of the celery (*Apium graveolens*), is obtained a colourless or pale-yellow oil, of penetrating odour, warm sweetish flavour, sp. gr. 0·881, and readily soluble in alcohol. At Grasse (S. France), the wild plant only is used, and yields about 1 lb. of oil from 400 lb.

Chamomile-oils.—The flowers of the common or Roman chamomile (see Drugs, p. 798) afford 0·06–0·08 per cent. of essential oil by aqueous distillation. It is at first bluish, but becomes yellowish-brown in the course of a few months; it has a pleasant lemon-like odour, and boils at 175° (347° F.). The yield of this oil from an acre of flowers is estimated at about 8 lb. At Mitcham, near London, the entire plants, deprived of their best flowers, are distilled, after drying in open sheds, excluding direct sunlight. The stills hold 1000–2000 gal., and a charge occupies 6–8 hours. The distillation is conducted at the lowest possible temperature, and, so soon as the contents of the retort have reached the boiling-point, the fire is withdrawn. The finest and most fragrant oil comes over during the first 3 hours of the process, and the receiver is then changed.

An essential oil is also distilled from the flowers of the German chamomile (see Drugs—Chamomile, p. 799). It is thick, dark-blue in colour, with a strong odour of the flowers, and a hot aromatic flavour.

Cinnamon- and Cassia-oils.—An essential oil, erroneously called "white cinnamon," is obtained by the aqueous distillation of the bark of *Canella alba* (see Drugs—Canella, p. 796); it is a mixture of caryophyllic (eugenic) acid, an oil resembling cajuput, and an oxygenized oil. It is not a commercial article.

Essential oils of considerable importance are derived from the true cinnamon of Ceylon, *Cinnamomum zeylanicum* (see Spices—Cinnamon). Foremost is that yielded by the bark, to the extent of ½–1 per cent., which is extensively distilled (aqueous) in Ceylon, and rarely in England. It is a golden-yellow liquid, with powerful cinnamon odour, sweet and aromatic but burning flavour, and sp. gr. 1·035. It is largely used in perfumery. Ceylon ships some 15,000–40,000 oz. annually of this oil, chiefly to England. A century ago, the average yearly sales by the Dutch E. India Co. were but 176 oz. The leaves afford a brown, viscid, essential oil, of clove-like odour, sp. gr. 1·053, sometimes exported from Ceylon; and a third oil is supplied by the root,—a yellow liquid, lighter than water, with an odour of camphor and cinnamon, and a strong camphoraceous flavour.

Various species of *Cinnamomum* occurring in Tropical Asia afford the so-called "cassia-bark" (see Spices—Cassia). From this bark, is distilled, notably in China, an essential oil agreeing chemically with that of Ceylon cinnamon-bark, but of less agreeable odour, and sp. gr. 1·066. The yield by distillation is about ¾ lb. of oil from 1 cwt. of bark. The oil is an export of no small importance from some Chinese ports. Pakhoi shipped 66,650 lb. in 1877, and 200 *piculs* (of 133⅓ lb.) in 1879; Macao exported about 480 *piculs* in 1879. A large proportion comes to Great Britain, but Hamburg seems to be the most important destination. The oil is used for perfuming soaps.

Citronella-oil.—One of the "grass-oils," called "citronella," is obtained from *Andropogon nardus* [*A. Martini*], attaining a height of 6 ft. and more. It grows wild abundantly in Singapore, and a large area is under cultivation with it, both in Ceylon and Singapore. In Ceylon, it is cut for distillation at any time of year, but mostly in December–January. The leaves are distilled with water, and yield over 3 oz. of essential oil from 1 cwt. The pure oil is thin, colourless, with strong aromatic odour, and acrid citron-like flavour. It is a growing article of trade. The shipments from Ceylon were 622,000 oz., value 8230*l.*, in 1864; in 1874, they were 1,163,074 oz. to the United Kingdom, 5713 oz. to British India, and 426,470 oz. to the United States; total, 1,595,257 oz., in addition to 842 doz. and 33 packages to the United States. Its almost only application out of India is for scenting soap, the consumption being very extensive. The best kind bears the name of John Fisher (of Singapore, and 43 Mincing Lane). Fisher's 950-acre estate on the island of Singapore now produces about 1 million oz. yearly of this oil.

Oils from other species of *Andropogon* are described under Ginger-grass and Lemon-grass (pp. 1422, 1423).

Clove-oil.—An essential oil is obtained from the flower-buds and flower-stalks of cloves (see Spices—Cloves) by aqueous distillation. This distillation is largely carried on in England. The proportion of oil present may amount to 16–20 per cent., but to extract the whole, the distillation must be long continued, the water being returned to the same material. The oil is a colourless or yellowish liquid, with powerful odour and flavour of cloves, and varying in sp. gr. from 1·046 to 1·058. It combines well with grease, soap, and spirit, and is one of the most extensively-used oils in perfumery. In Germany, clove-oil is often adulterated with carbolic-acid (phenol).

Clove-bark-oil.—The bark of *Dicypellium caryophyllatum*, a native of Brazil, affords by aqueous distillation an essential oil bearing great resemblance in all its properties to clove-oil.

Coffee-oil.—Coffee-berries (see Coffee, pp. 691–722) contain a proportion of essential oil varying from 8 to 13 per cent. This is partially given off during the roasting process (see Beverages—Coffee, pp. 422–3), and at least half is wasted, the remainder producing the characteristic odour and flavour of the berries. By the existing method of roasting coffee, it is scarcely possible to collect the volatilized oil, on account of its being so largely emitted during the shovelling of the beans in the open air when withdrawn from the roasting-drums. It is suggested that the drums should be in connection with an exhauster, so as to condense the oil in a receiver, and at the same time cool the beans sufficiently to prevent ignition. It is thought that the oil might be profitably used in making liqueurs.

Copaiba-balsam-oil.—Copaiba-balsam (see Resinous Substances—Copaiba) contains 40–60 per cent. of volatile oil, according to its age and botanical origin. It is obtained by aqueous distillation. It is a thin, colourless body, resembling the balsam in odour and flavour, boiling at 245° (473° F.) or even higher, soluble in 8–30 parts of alcohol at 0·830 sp. gr., and varying in density from sp. gr. 0·88 to 0·91.

Coriander-oil.—The fruits of *Coriandrum sativum* (see Spices—Coriander) yield 0·7–1·1 per cent. of volatile oil, which is extracted by bruising them, and subjecting to aqueous distillation The oil is colourless or yellowish, with the odour and flavour of the fruits, sp. gr. 0·859–0·871, and boils (not constantly) at 150° (302° F.).

Cubebs-oil.—The fruits of *Piper Cubeba* (see Drugs—Cubebs, p. 809) yield 4–13 per cent. of volatile oil by aqueous distillation. This variation is due in part to the constitution of the drug, but also to the alterability of the oil. It is thick and colourless, the portion which distils last in rectifying having almost the consistence of butter; its sp. gr. is 0·936; it is composed of a small quantity of an oil ($C_{10}H_{16}$) boiling at 158°–163° (316½°–325½° F.), and two other oils (each $C_{15}H_{24}$) boiling at 262°–265° (503½°–509° F.); its odour is faint and aromatic, and it has a warm flavour of camphor and peppermint.

Other oils from *Piper spp.* are described under Matico and Pepper (pp. 1424, 1425).

Dill-oil.—The crushed fruits of *Anethum graveolens* (see Drugs—Dill, p. 810), submitted to aqueous distillation, yield 3–4 per cent. of essential oil, composed of two or more hydrocarbons. The oil is skimmed from the distillate, and the latter forms commercial dill-water. The oil may be used in mixtures for perfuming soap.

Elder-oil.—The flowers of the elder (*Sambucus nigra*) afford a very small percentage of essential oil by distillation. It has a buttery consistence, light-yellow colour, a strong odour of the flowers, and a bitter, burning, afterwards cooling flavour.

Elemi-oil.—Manilla elemi (see Resinous Substances—Elemi) affords nearly 10 per cent. of volatile oil by aqueous distillation. It is colourless, neutral, with a fragrant odour of the resin, an acrid flavour, sp. gr. 0·861 at 15° (59° F.), and boils at 166°–174° (331°–363° F.).

Eucalyptus-oils.—Essential oils of daily increasing importance are obtained by aqueous distillation of the leaves and branchlets of many species of *Eucalyptus* (see Timber). The oil of *E. amygdalina* (3·313 per cent.) is thin, pale-yellow, of pungent, coarse, lemon-like odour, mild, cooling, afterwards bitter flavour, sp. gr. 0·881 at 15° (59° F.), boils at 165°–188° (329°–370½° F.), becomes resinous in the air, deposits a stearoptene at −18° (0° F.), which melts at −3° (26½° F.); the oil is used in medicine, disinfecting, and perfumery. *E. oleosa*: 200 oz. from 1000 lb. of leaves and twigs, thin, fluid, pale-yellow; mild, camphoraceous, turpentinous flavour; mint-like odour; sp. gr. 0·911; boils at 161°–177° (322°–350½° F.). *E. sideroxylon*: limpid, thin, pale-yellow, odour and flavour like *E. oleosa*, sp. gr. 0·923, boils at 155°–178° (311°–352½° F.). *E. goniocalyx*:

pale-yellow colour, pungent, penetrating, rather disagreeable odour, very unpleasant flavour, sp. gr. 0·918, boils at 152°–175° (305½°–347° F.). *E. globulus*: 0·719 per cent., thin, very pale-yellow colour, cajuput-like odour, cooling, mint-like flavour, sp. gr. 0·917, boils at 149°–177° (300°–350½° F.), used medicinally. *E. corymboza*: colourless, slight odour of lemon and rose, bitterish, camphor-like flavour, sp. gr. 0·881 at 15° (59° F.). *E. obliqua*: reddish-yellow colour, mild odour, bitter flavour, sp. gr. 0·899, boils at 171°–195° (340°–383° F.), becomes turbid at −18° (0° F.). *E. fissilis*: pale reddish-yellow colour, odour like *E. obliqua*, sp. gr. 0·903, boils at 177°–196° (350½°–385° F.). *E. odorata*: pale-yellowish, with greenish tinge, aromatic odour, sp. gr. 0·899–0·922, boils at 157°–199° (314½°–390° F.). *E. rostrata*: pale-yellow to reddish-amber, odour and flavour like *E. odorata*, sp. gr. 0·918, boils at 137°–181° (278½°–358° F.). *E. longifolia*: oily consistence, cooling, aromatic flavour, fragrant, camphor-like odour, sp. gr. 0·940, boils at 194°–215° (381°–419° F.). *E. viminalis*: pale yellowish-green, mild disagreeable odour, sp. gr. 0·921, boils at 159°–182° (318°–359½° F.). *E. citriodora*: yields fairly, and is a good cosmetic. *E. dumosa*: excellent for oil- and spirit-varnishes. All these oils are manufactured on an industrial scale by J. Bosisto, of Richmond, Victoria. They (that of *E. oleosa* is most commonly used) dissolve the following substances in a descending degree:—Camphor, rosin, mastic, callitris-sandarac, elemi, sandarac, kauri, dammar, asphalt, xanthorrhæa-resin, dragon's-blood, benzoin, copal, amber, anime, shellac, caoutchouc, bees'-wax; guttapercha is not dissolved.

Fennel-oil.—The fruits of *Fœniculum officinale* [*vulgare*] afford a volatile oil by aqueous distillation. It is pale-yellow, with a sweetish aromatic odour and flavour of the fruit, sp. gr. 0·968 at 20° (68° F.); solidifies below 10° (50° F.); may be used for perfuming soap. The plant grows wild in S. France, and is distilled entire in July–August, giving 1 lb. of oil from 500 lb.

Fusel-oil.—The name "fusel-oil" is applied to a series of volatile liquids obtained in the rectification of alcoholic liquors made by fermenting grain, potatoes, &c., and whose separation is a matter of great importance (see Alcohol, p. 212). The oil varies much in quantity and composition, according to its source; it is practically always present in greater or less degree in commercial spirits. It is employed industrially as a source of amylic alcohol, which is its chief constituent.

Galangal-oil.—The rhizome of *Alpinia officinarum* (see Spices—Galangal), by aqueous distillation, affords about 0·7 per cent. of an essential oil, with an odour and constitution resembling cajuput-oil, and readily soluble in alcohol.

Galbanum-oil.—Galbanum (see Resinous Substances) affords about 7 per cent. of volatile oil by aqueous distillation. It is colourless or slightly yellowish, with mild, aromatic flavour, galbanum-like odour, sp. gr. 0·904, and boils at 160° (320° F.).

Gale-oil.—The leaves of *Myrica Gale*, when distilled with water, give a brownish-yellow essential oil, thickish at 12° (53½° F.), of peculiar, pleasant, balsamic odour, mild, then hot and lastingly styptic flavour, sp gr. 0·876, soluble in 40 parts of alcohol at 0·875 sp. gr.

Garlic-oil.—The bulbs of garlic (*Allium sativum*), when distilled with water, afford a volatile oil, which does not seem to pre-exist in the plant. In the crude state, it is brownish-yellow, with an intense odour of garlic; it is slowly soluble in water, and suffers partial decomposition by rectifying. An identical oil is yielded by several *Cruciferæ*. (See also *Allium*, p. 1414).

Geranium-oil.—The name "geranium-oil" is properly confined to oils afforded by different species of *Pelargonium*, but is often applied also to ginger-grass-oil (p. 1422). *P. Radula*, the rose-leaved geranium, is cultivated in France, both in the south, and at Montfort-Lamaury, in the department Seine-et-Oise. It is propagated by slips taken in September, and generally planted out in February, though the latter may be done at almost any season. The cultivation is very easy, and, with proper manuring and irrigation, the plants grow 3–4 ft. high, and yield an abundance of foliage, which is reaped by a sickle. About 3000 plants occupy an acre, and they require renewing every 3–4 years. The leaves and flowers are distilled with water, 1 cwt. yielding about 2 oz. of essential oil. The oil obtained in Seine-et-Oise has a better odour than that produced in S. France. It is colourless, greenish, yellowish, or brownish, the last being most esteemed, boils at 206°–220° (421°–428° F.), and solidifies at 16° (61° F.); the odour closely resembles that of the rose. *P. odoratissimum* is much cultivated in Algeria and Valencia, and yields a very similar oil. It requires deep, well-worked, fertile soil, and succeeds well in the red soils of Sabel, in Alger, and in the cool, sandy soil of Staonéli. The slips are planted in lines, 18–26 in. by 8–10 in. apart, at the beginning of winter, and yield 3 cuttings annually. The cultivation is maintained for 3 years, and gives 250–300 and even 475 cwt. of leaves per *hectare* (of 2½ acres) per annum. The whole plant is cut down to within 4 in. of the ground. The first cutting, in May, requires 1200–1400 lb. of leaves to afford 1 lb. of essential oil, but in July, 800 lb. will give the same yield. All these geranium-oils are used in perfumery, and largely as adulterants of otto of rose (see Rose-oil, p. 1427). They are likewise themselves adulterated extensively with ginger-grass-oil (p. 1422).

Ginger-oil.—The rhizomes of *Zingiber officinale* (see Spices—Ginger), when distilled with water, afford a thin, yellowish, essential oil, with a strong odour of ginger, a burning aromatic flavour, sp. gr. 0·893, boiling at 246° (475° F.).

Ginger-grass-oil.—An essential oil known as "ginger-grass," often also as *rusa* or "rose-oil," and as "geranium-oil," is the produce of *Andropogon Schœnanthus*, a grass indigenous to N. and Central India. The leaves are distilled in the Khandesh collectorate of the Bombay presidency. The oil produced in the Namar district of the Nerbudda valley is sometimes called "grass-oil of Namar." The export of the oil from Bombay during the year ending March, 1867, was 41,643 lb. It is shipped to England, and to the ports of the Red Sea. Its largest consumption is for the adulteration of otto of roses (see Rose-oil, p. 1427).

Essential oil from other species of *Andropogon* are described under Citronella and Lemon-grass (pp. 1419, 1423).

Hop-oil.—The female flowers of *Humulus Lupulus* (see Hops, p. 1130), distilled with water, afford a fragrant essential oil. The yield from 120 lb. of New Kentish hops, according to Piesse, was 8 oz.; that from 3-year old Bavarian, 11 oz. The oil is thin, colourless or yellowish, with a penetrating narcotic odour, hot, slightly bitter flavour, sp. gr. 0·910; it is not yet used in perfumery.

Hyssop-oil.—On aqueous distillation of the herb hyssop (*Hyssopus officinalis*), an essential oil, without colour, of peculiar odour, acrid, camphoraceous flavour, and neutral reaction, is obtained; its sp. gr. is 0·88–0·98; in contact with the air, it becomes yellow, and changes to a resin; its boiling-point is 142°–162° (287½°–323½° F.). The plant is largely grown around Grasse (S. France), and affords 1 lb. of oil from 400–500 lb.

Ilang-ilang-oil.—A minute quantity of remarkably pleasant-odoured oil is distilled from the flowers of *Cananga odorata*, a common plant in the E. Indies, but especially in the Philippines, where it is cultivated for its perfume. The oil is largely adulterated with an oil distilled from the flowers of *Michelia Champaca*, a native of the same localities. The yield of oil obtained by German distillers in the Philippines is about 25 *grm.* from 5 *kilo.* of the flowers (or 0·5 per cent.). The tree may be cultivated very easily in all warm countries, and commends itself to Australian horticulturists. The annual European consumption is said to be about 200 *kilo.* in Paris, Nice, and Grasse, 50 *kilo.* in London, and 50 *kilo.* in Leipzig, Berlin, and Frankfort. According to one authority, "Macassar-oil" is coco-nut-oil in which the flowers of *Cananga odorata* and *Michelia Champaca* have been digested (see also Macassar-oil, p. 1394).

Iva-oil.—By the aqueous distillation of the whole herb *Achillea moschata* before flowering, is obtained a clear, yellowish, liquid oil, of very pleasant, strongly ethereous odour, and warm bitter flavour, boiling at 180°–210° (356°–410° F.).

Jasmine-oil.—The jasmine (*Jasminum odoratissimum*) is extensively cultivated for the delightful odour contained in the essential oil of its flowers. It is grown as a small bush, by grafting the Spanish variety upon 2-year old stems of wild jasmine. It requires moist soil or irrigation, and liberal pruning every year; it is planted in rows, with horizontal poles for support, and about 8000 to an acre; the plants are not in full bearing till the third year after grafting, but when mature, every 1000 plants give about 60 lb. of flowers annually, or about 500 lb. an acre. The flowers appear in July–October, those of August–September being most fragrant. The flowers are grown chiefly in S. France, notably around Cannes; also in Algeria and Tunis. The essential oil may be obtained by aqueous distillation, repeatedly supplying fresh flowers to the same water; but the cost of production is extremely great, and it is more usual to impregnate fatty oils by the absorption process, described on p. 1456.

Jonquil-oil.—An essential oil is extracted from jonquil-flowers (*Narcissus Jonquilla*) by ether. It is yellow, of buttery consistence, and with a pleasant odour of the flowers.

Juniper-oil.—The berries of *Juniperus communis*, when distilled with water, afford a colourless or yellowish oil, with a strong odour of the fruit, sp. gr. 0·847–0·870, slightly soluble in alcohol. The oil of ripe fruits boils at 205° (401° F.), and deposits a stearoptene in the cold. The unripe fruits give in addition an oil boiling at 155° (311° F.). The plant grows in the N. regions of both hemispheres, but the supply of berries comes chiefly from S. France, and in a minor degree from Austria and Italy. The fruits are not mature till about the end of the second year after their appearance. Ripe berries distilled immediately give 0·4 per cent. of oil, which is increased to 0·75 per cent. by previous maceration in cold water.

Laurel-oils.—An essential oil is obtained by distilling the berries of the sweet bay (*Laurus nobilis*) with water, and is often called "bay-oil." It is greenish-yellow, of thickish consistence, with an odour of turpentine and laurel, sp. gr. 0·932.

Another essential oil is procured from *Oreodaphne opifera*, in British Guiana, and on the Orinoco, by boring holes into the heart of the tree. It flows out in a clear stream, and is collected in basins. When rectified and desiccated, it is colourless, with an odour of turpentine and lemons, and aromatic pungent flavour; its sp. gr. is 0·864; boiling-point, 150°–163° (302°–325½° F.); it is used medicinally, and is an excellent solvent of indiarubber. A third oil is distilled from the fruit of this tree.

Oreodaphne californica (the Californian bay laurel), is an evergreen tree indigenous to California and the Pacific slope, growing abundantly in the vicinity of ravines, and moist shady localities. All parts yield a volatile oil, but the leaves give most—4 per cent. by distillation. It is straw-coloured, limpid, with pungent aromatic odour, warm camphoraceous flavour, sp. gr. 0·936. It has medicinal virtues.

A fixed oil from the laurel is described under that section (see p. 1393).

Lavender-oil.—Several species of *Lavandula* are cultivated for the sake of their essential oil. *L. vera*, commonly called "female lavender," is a native of S. Europe, N. Africa, and Persia; it is the kind chiefly grown, and occupies a large area of ground in France, as well as at Mitcham (Surrey), and Hitchin (Herts), in England. *L. Spica*, or "male lavender," is raised principally on the Continent, and affords an inferior product, termed "oil of spike." A lavender plantation in this country should be sun-exposed, and away from hedges and trees, as these tend to keep the air too moist, and make the flowers liable to be cut off by spring frosts. The best soil is loam, with chalky subsoil. In October, slips from old plants are placed in previously-prepared beds, and kept carefully clipped for 12 months. At the end of this time, they are set out in fine weather, 3 ft. apart in rows 4 ft. apart (or 3547 plants on an acre). They are not yet allowed to flower, but are still clipped, and regularly dressed with short dung, or superphosphate of lime, to strengthen them. The harvest takes place in August, when the plants are cut down by the sickle, and immediately packed in quantities of about ½ cwt. in pieces of bast matting (see Fibrous Substances—*Raphia spp.*, p. 994, *Tilia*, p. 998), for protection from the sun during conveyance to the stills. The yield is greatest and best from 4-year-old plants; but it is a singular fact that the product from 2-year-old plants is larger than from those of either 1 year or 3 years. Sometimes the crop is continued on the same ground for 6 years in succession, by judiciously replacing old plants; but more commonly, some other crop is raised every fourth year. The yield of oil varies greatly with the season and the soil. The average at Mitcham is 10–12 lb. an acre. Perks, at Hitchin, removes the flowers from the stalks before distilling, and finds that though the operation of stripping entails an extra expense, the product is greatly improved in quality, and very little less in quantity. Usually the whole herb is thrown into the still, in which case, the oil is divided into 1sts and 2nds; the former, including about $\frac{15}{16}$ of the total, is reserved for making "lavender-water," while the latter serves for perfuming soaps and greases. The best French oil is got from flowers grown on the highest points in the department Alpes-Maritimes; 150–200 lb. of flowers give 1 lb. of oil in a good season. The oils of *L. Spica* and *L. Stœchas* are used by painters on porcelain, and in artists' varnishes. The oil produced in England fetches four times the price of any other. It is thin, pale-yellow, with a pleasant odour of the flowers, a burning, bitter, aromatic flavour, sp. gr. 0·876–0·880, boils at 185°–188° (365°–370½° F.), and dissolves readily in alcohol.

Lemon-oil and Citron-zeste.—The rind of the Lemon (see Fruit—Lemons, p. 1025), when rasped and subjected to expression, or when distilled, affords an essential oil, known as "essence of lemon," or "citron-zeste," according to the method adopted. The oil is extracted largely in the neighbourhood of Palermo, in Sicily, at Reggio, in Calabria, and at Mentone and Nice, in France. The fruits are used while still rather green and unripe, being then richer in oil; only small and otherwise unmerchantable fruit is employed. The operation is conducted in November–December. In Sicily and Calabria, the "sponge process" is adopted, as described in another section of this article (see p. 1457). The yield is very variable, 400 fruits affording 9–14 oz. of oil. The pulp and exhausted peel are pressed, to extract "lemon-juice," and then sometimes distilled. At Mentone and Nice, recourse is had to the *écuelle*, whose construction and use is also recorded in another portion of this article (see p. 1457). These kinds of oil are much superior to a third which is obtained by grating the peel of fresh lemons, or of those which have been submitted to the *écuelle*, and distilling with water. The oils obtained by the sponge and *écuelle* are thin liquids, of faint-yellow colour, exquisite odour, and bitterish aromatic flavour; their sp. gr. is 0·83–0·88, and their boiling point, 170°–180° (338°–356° F.). The oil (or essence) of lemon is shipped mostly from Messina and Palermo, in copper bottles, called "jars" or *ramieri*, holding 25–50 *kilo.* or more, sometimes in tin bottles of less size. The total quantity of lemon-, orange-, and bergamot-oils exported from Sicily in 1871 was 368,800 lb., value 144,520*l.*, about ⅔ coming to England; and the exports from Messina in 1877 were 306,948 *kilo.* The British imports of lemon-oil alone are estimated at 85,000–90,000 lb. annually. It is most extensively consumed in perfumery.

Lemon-grass-oil.—The essential oil known as "lemon-grass," "verbena," or "Indian melissa," is obtained from the leaves of *Andropogon citratus*, a large coarse grass, found under cultivation in various islands of the E. Archipelago, and growing wild on extensive tracts of land in Ceylon; it rarely or never bears flowers. It is grown especially for its oil in Ceylon and Singapore, on the same estates with citronella, and is commonly met with in gardens in India, Java, and the Moluccas. It is more highly esteemed than citronella-oil, and is produced in much less quantity. Ceylon exported 13,515 oz. of this oil in 1872, more than half of which went to the United States. The best brand is Fisher's (of Singapore). The most important use of this oil is for adulterating verbena-oil; it is also used for perfuming soaps and greases.

Other essential oils from *Andropogon spp.* are described under Citronella and Ginger-grass (pp. 1419, 1422).

Lilac-oil.—By ethereal extraction, the flowers of *Syringa vulgaris* yield an amber-yellow oil, with an odour of the flowers. For perfumery purposes, the oil is obtained by absorption with pure grease.

Linden-oil.—The flowers of the European lime or linden (*Tilia europæa*), described elsewhere (see Fibrous Substances—*Tilia*, p. 998), submitted to aqueous distillation, give a colourless or yellowish oil, with a strong pleasant odour of the flowers, and sweetish flavour ; it dissolves readily in alcohol. It is imitated by perfumers.

Mace- and Nutmeg-oils.—Besides the fatty oils afforded by mace and nutmegs (see pp. 1396–7), they yield essential oils by aqueous distillation. That from mace is thin, yellowish, with a strong odour of mace, burning aromatic flavour, deposits no solid at −12° (10½° F.), begins to boil at 160° (320° F.), the temperature rising to 180° (356° F.). Nutmeg-oil is thin, nearly colourless, with strong odour and flavour of the seeds, sp. gr. 0·850, deposits no sediment at −7° (19½° F.), commences to boil at 160° (320° F.), the temperature rising to above 200° (392° F.). These oils are used for scenting soap.

Marjoram- or Origanum-oils.—The sweet marjoram (*Origanum Marjorana*) affords an essential oil by distilling the whole herb with water. It is cultivated for this purpose in S. France. The ordinary yield is 1 lb. of oil from 2 cwt. of the herb, but it varies exceedingly with the culture and season. The oil is thin, of light-yellow or yellowish-green colour, with a powerful odour of the herb and peppermint, of warm, acrid, slightly bitter flavour, sp. gr. 0·8854 at 17° (62½° F.), boils at 163° (325½° F.).

Wild marjoram (*Origanum vulgare*), collected in Kent, gives scarcely 1 oz. of oil from 70 lb. of the herb. The oil is brownish-yellow, with a strong odour of the herb, an acrid, aromatic flavour, and sp. gr. 0·86–0·90.

Both these oils are said to be used for perfuming soap, but it is more than probable that they are generally replaced by the essential oil of thyme (see Thyme-oil, p. 1431).

Matico-oil.—An oil is obtained from the leaves of *Piper angustifolium* (see Drugs—Matico, p. 818), by distillation. It is somewhat thick, pale-green, of strong, camphoraceous odour and flavour, and thickens and crystallizes by keeping.

Other oils from *Piper spp.* are described under Cubebs and Pepper (pp. 1420, 1425).

Meadow-sweet-oil.—The flowers of *Spiræa Ulmaria*, when distilled with water, afford a colourless oil, with an odour of salicylous acid, slightly burning flavour, readily soluble in alcohol, partly solidifying by cold. It is not availed of by perfumers.

Mehudee-oil.—An essential oil called *mehudee* is distilled by the natives of some parts of India, notably in Lucknow, from the leaves of *Lawsonia alba* (see Dyestuffs—Henna, p. 858). It is remarkably and delightfully fragrant.

Mignonette-oil.—The flowers of *Reseda odorata*, submitted to extraction by ether, yield a thick oil, of yellowish colour, and most pleasant odour. By perfumers, it is extracted by absorption.

Milfoil-oils.—Various parts of the common milfoil (*Achillea Millefolium*) yield essential oils by aqueous distillation. That of the flowers is dark-blue, sp. gr. 0·92. That of the herb is blue, of a deeper tint than chamomile-oil, thick, almost of buttery consistence when cold, of strong odour, slightly burning flavour of the herb, sp. gr. 0·852–0·917. That of the fruits is greenish. That of the root is colourless, or slightly yellow, with peculiar, disagreeable, somewhat valerian-like odour, and unpleasant flavour.

The oil obtained by aqueous distillation of the herb, flowers, or fruits of showy milfoil (*Achillea nobilis*) is thick, pale-yellow, of more refined and camphor-like odour than common milfoil, aromatic, camphoraceous, bitterish flavour, sp. gr. 0·97–0·98, and dissolves readily in alcohol.

Another *Achillea*-oil is described under Iva (p. 1422).

Mugwort-oil.—The root of *Artemisia vulgaris*, when distilled with water, gives a butter-like crystallizing oil, of pale greenish-yellow colour, penetrating peculiar odour, nauseous, bitterish flavour, and readily soluble in alcohol.

Other *Artemisia*-oils are described under Tarragon, Wormseed, and Wormwood (pp. 1431, 1432).

Mustard oil.—Besides the fatty oil obtained from mustard (see p. 1396), a volatile oil is produced (it does not pre-exist), by distilling macerated brown mustard-seed with water, which is added at a temperature not exceeding 50° (122° F.). The oil is colourless or yellowish, of intensely penetrating odour and flavour of mustard, sp. gr. 1·017, boils at 148° (298½° F.), dissolves slightly in water, readily in alcohol and ether, and in 3 times its weight of cold sulphuric acid at 168° Tw.

Myrrh-oil.—When myrrh (see Resinous Substances—Myrrh), is distilled with water, 100 lb. will yield about 8 oz. of thickish, pale-yellow essential oil, having an odour and flavour of myrrh.

Myrtle-oil.—The leaves, flowers, and fresh fruits of the myrtle (*Myrtus communis*), by aqueous distillation (in September), yield a yellowish or greenish-yellow oil, of great fragrance, about 5 oz. being obtained from 1 cwt. of leaves. Perfumers mostly replace it by an artificial compound.

Nasturtium-oil.—The seeds of *Nasturtium officinale*, under distillation, give an oil boiling at 120°–280° (248°–536° F.).

Neroli-oil.—The fresh flowers of the bitter orange (see Fruit—Oranges, p. 1025), by aqueous distillation, yield 0·6–0·7 per cent. of essential oil, the extraction of which is carried on chiefly at Grasse, Cannes, and Nice, in S. France; also in Algeria. The finest trees afford about 30 *kilo.* of flowers. The oil is commonly adulterated with bergamot and petit-grain (qq. v.), $\frac{1}{8}$ of the former and $\frac{3}{8}$ of the latter being added to $\frac{4}{8}$ of true neroli. The yield from 1 ton of flowers is about 40 oz., worth 20*l.*, the residuary water, known as "orange-flower water," or *aqua Naphæ*, is worth an additional 10*l.* The flowers of the sweet orange yield less than half the amount of oil; those of the shaddock (p. 1026) make a very good neroli. Pure neroli-oil is brownish, of most fragrant odour, bitterish aromatic flavour, sp. gr. 0·889 at 11° (52° F.). It is very largely used in perfumery.

Other oils from the *Citrus* genus are described under Bergamot, Cedrat, Lemon, Orange, and Petit-grain (pp. 1417, 1419, 1423, 1425, 1427).

Olibanum-oil.—When olibanum (see Resinous Substances—Olibanum) is subjected to aqueous distillation, it affords a thin, yellowish oil, of pleasant turpentinous odour, sp. gr. 0·866, and boiling at 162° (323½° F.).

Orange-oil.—The scarcely-ripe fruit of both the sweet and bitter variety of orange (see p. 1025) is made to yield an oil from the rind, by means of the "sponge" or the *écuelle* process (see p. 1457), which is largely produced at Messina and in S. France. That obtained from the sweet orange is termed *essence de Portugal*; that from the bitter, *essence de bigarade*; the latter is much the more valuable. Both are used in liqueur-making and perfumery.

Other *Citrus*-oils are described under Bergamot, Cedrat, Lemon, Neroli, and Petit-grain (pp. 1417, 1419, 1423, 1425, 1427).

Orris-oil.—Orris-root (see Perfumes—Orris-root), dried, and then subjected to aqueous distillation, affords an exceedingly minute quantity (about 0·1 per cent.) of volatile oil, not to be found in the living root.

Parsley-oil.—The fruits of the parsley (*Carum Petroselinum*), distilled with water, afford a thin essential oil, greenish-yellow when fresh, colourless when rectified, with an odour of the fruit, sp. gr. 1·01–1·04, solidifies at 2°–8° (35½°–46½° F.), boils at 160°–170° (320°–338° F.), and dissolves readily in alcohol. At Grasse (S. France), the yield is 1 lb. of oil from 250–300 lb.

Patchouly-oil.—An essential oil is extracted from patchouly or *pucha-pat* (*Pogostemon Patchouly* [*Plectranthus crassifolius*]), a native of Silhet, Province Wellesley, Singapore, various islands in the E. Archipelago, and Java. There are two kinds, known as *toun-tilâm* or *tilâm-outan*, and *tilâm-wangi*; the former is the common and less fragrant, the latter is the cultivated and more admired. Fisher, of Singapore, who produces about $\frac{4}{5}$ of all the patchouly-oil of commerce, proceeds as follows:—The plants are grown in rows 4–5 ft. apart, in stiffish clay containing a small percentage of silica. They are raised from cuttings struck in the open, and sheltered from the sun by coco-nut shells till rooted. The gathering is done in fine weather and after the dew is off; the tops and green parts are broken off by hand, rejecting all yellow or decayed leaves, and all the woody stems. The selected parts are carefully dried in the shade on bamboo racks, with frequent turning. When so far dried as to leave just sufficient moisture to favour slight fermentation, they are piled in heaps, and allowed to heat gently; they are again spread out and dried (but not to absolute dryness), and are immediately distilled. The distillation is effected by steam generated in a separate vessel, and at a pressure not exceeding 30 lb. a sq. in., the still being usually steam-jacketed to prevent condensation. The yield of oil is about ¼ oz. from 1 lb. of leaves; it would be greater by high-pressure steam, but of ranker quality. This oil is sent to London in 22-oz. bottles. Quantities of the more or less inferior and mixed leaves are sent to France and Germany for distillation, but the oil from them is quite a different article. The sp. gr. of Indian and Singapore oils is 0·9554–0·9592, and of a French sample, 1·0119, at 15½° (60° F.). It is much esteemed for perfumery purposes.

Pepper-oil.—The fruits of *Piper nigrum* (see Spices—Pepper), when distilled with water, give a thin, colourless oil, of hot, peppery odour and flavour, sp. gr. 0·864, boiling at 167½°–170° (333°–338° F.).

Other *Piper*-oils are described under Cubebs and Matico (pp. 1420, 1424).

Peppermint-oil.—Peppermint (*Mentha piperita*) yields an essential oil second to none in commercial importance. The plant is found in several parts of England and the Continent, and is extensively cultivated in England, France, Germany, and N. America. It prefers good garden soil, and abundance of moisture, yielding a better oil in a temperate climate than in an arid one. The ground is well tilled some 8–10 in. deep, and the planting takes place in April–May, according to the season. The plants send out a number of runners, which take root at short intervals. These are cut off in spring when about 1 in. high, and are set out in plantations at about 1 ft. apart each way. If the soil is not very humid, or the weather wet, watering will be compulsory. Until July–August, the period of the first harvest, one or two weedings are necessary. After the cropping, runners start in all directions, take root, and cover the ground, sometimes even affording stems for a second gathering. Between August and November, one or two more weedings are required; and towards winter, the plants are covered with a light bed of straw sprinkled with mould or dung. In the second year, the plants have completely occupied the soil; they grow with great vigour, and attain a height of over 2 ft. Two weedings generally suffice during the second year; one crop is cut in July–August, and a second of less importance in the autumn, the usual precautions being taken before winter sets in. In the 3rd and 4th years, the growth relaxes, and the ground has become completely filled with an inextricable mass of runners and roots. The locality is then changed, and the soil is thoroughly well ploughed up; some few gardens, however, will last 5 years. The weight of the crop, and the yield of oil from the plants, vary exceedingly with the seasons. The 6-years' average on a French plantation of 31 *ares* of (119½ sq. yd.), including plants from 1 to 4 years old, was 145 *kilo.* of fresh plants per *are* all round, or say 115 cwt. from an acre.

The herb, when cut, is almost universally allowed to dry on the ground before distillation. This needs the greatest degree of care, for though an incipient fermentation may, and probably does, increase the quantity and improve the quality of the oil, any excess would result in total destruction. The advantage of sun-drying the herb before distillation has been proved by experiments on a large scale, the product being 7 per cent. greater, and of superior fragrance. The main reason for this appears to be that, in the fresh plant, the oil-cells are so strongly protected that it is difficult to rupture them and secure their contents, while the prolonged boiling to which the herb is subjected with this object tends to destroy the natural fragrance of the oil. Some extra cost is entailed for labour in drying; but as it is a common custom for small cultivators to hire the use of a still at so small a charge, irrespective of the weight, an advantage is gained in having the herb dry, as more can then be distilled at once. The best moment for distilling is when the flowers are blowing, the quality of the oil being then superior, though the quantity is perhaps greater somewhat later. The flowering lasts about a month, and the still-accommodation should suffice to complete operations within that time. Usually the entire herb is distilled, for though the leaves and tops afford the most and best oil, the exclusion of the stems reduces the product in quantity, and entails additional labour.

The stills used in Europe are most commonly heated by fire; but in America, preference seems to be given to steam-heating the herb in wooden stills. A good form of still for fire-heat is such as is used for distilling brandy from grape-marc in France, built into masonry, and protected from direct action of the fire, with a copper strainer fixed about 3–4 in. from the bottom for the support of the herb. The distillation is conducted at the lowest possible temperature, and the products are cooled and separated in the ordinary manner, as described on p. 1457. In England, the water that comes over with the oil is mostly allowed to run away, and none of it is used for a second charge. In France, preference is given to the water of former charges. The advantage of old water is that, being already saturated with essential oil, it will not abstract more from the fresh plant; but it is impossible to obtain oil of the highest quality with old waters. The duration of the operation depends upon the firing, and averages about 2½ hours. The spent herb is taken out, dried, and used as cattle-food in America; here it seems to be disregarded. The water remaining in the still after each operation becomes very foul; the still must therefore be washed out every 2–3 days. The yield of oil is extremely variable. In England, it is usually reckoned to average 8–12 lb. from an acre, or 2½–3½ lb. from a ton of dried herb, say 0·11–0·15 per cent.; but some growers pretend to get 6 lb. from a ton, or 0·26 per cent. The results obtained by M. L. Roze from his plantations in France were as follows:—In the 6 consecutive years 1856–61, 26,639 *kilo.* of the plant in flower, weighed within 24 hours of cutting, and distilled entire, gave a mean of 1 *kilo.* of oil from each 609 *kilo.* of plant, the maximum quantity required for 1 *kilo.* having been 638 *kilo.*, and the minimum 548 *kilo*; the mean would be 2⅕ lb. of oil from 1342 lb. of almost fresh herb. The average in America is said to be 7 lb. from an acre of plant, but Stearns makes it exceed the English yield.

The English localities where peppermint is cultivated are Mitcham, in Surrey (500 acres in 1850, 219 in 1864); Wisbeach, in Cambridgeshire; Market Deeping, in Lincolnshire (150 acres in 1871); and Hitchin, in Herts. At Mitcham, two varieties are distinguished: "black," having purple stems, hardier, more prolific, but inferior product; and "white," with green stems, a much more delicate and valued product. The chief French peppermint-gardens seem to be at Sens (department of Yonne), on the flats at the confluence of the Yonne and the Vanne. In Germany, Cölleda, near Leipzig, is the centre of a production of 40,000 cwt. of the herb annually. The cultivation in the American States of S. Michigan, W. New York, and Ohio, exceeds all the European localities combined. Michigan has 2100 acres under this crop, 2000 of which are in St. Joseph county, which possesses 100 distilleries, turning out 15,000–30,000 lb. of oil yearly. New York and Ohio total about 1000 acres between them. The annual crop of peppermint-oil for the whole world is estimated at 90,000 lb. One dealer despatched 57,365 lb. from America in 1870;

and the receipts at Hamburg in 1876 were 25,840 lb. from America, and 14,890 lb. from England. Its commercial value varies widely, Mitcham oil bringing twice or thrice the price of the best American; and even the Mitcham oil itself is by no means constant. A fertile source of depreciation is the presence of weeds among the herbs, necessitating laborious care when preparing the plant for distillation; sometimes other species of *Mentha* usurp the ground, and ruin the fragrance of the product. The American oil is frequently adulterated with castor-oil and alcohol.

Peppermint-oil is colourless, yellowish, or greenish; of peculiar odour; burning, camphoraceous, then cooling flavour; sp. gr. 0·84–0·92; boils at 188°–193° (370½–379½° F.); dissolves readily in alcohol; cooled to −4° (25° F.), sometimes deposits menthol or peppermint-camphor. It is used in medicine (p. 819), confectionery, perfumery (less in England than on the Continent), and largely by sanitary engineers for testing joints and traps.

Other oils afforded by *Mentha spp.* are as follows:—*M. Pulegium* (pennyroyal), sp. gr. 0·927, boils at 183°–188° (361½°–370½° F.). *M. viridis* (spearmint), see p. 1431. *M. australis*, resembles 2nd quality peppermint-oil. *M. gracilis*, with an odour of peppermint and pennyroyal, sp. gr. 0·914. *M. laxiflora*, sp. gr. 0·924, coarse odour; fiery, bitter, nauseous flavour. Much more important than these, is a peppermint of China and Japan, which E. M. Holmes considers most like *M. canadensis*. This plant is distilled at Canton, whence an export of 800 lb. of the oil, valued at 30*s.* a lb., was specified in 1872; there are also large plantations of it in Japan, and the oil (frequently adulterated) is shipped from Hiogo and Osaka. These Chinese and Japanese oils afford much more menthol than other kinds. Seeds of the plant and quantities of the camphor (menthol) yielded by it are imported into this country by T. Christy and Co., 155 Fenchurch St., London.

Petit-grain-oil.—The oil or essence of petit-grain is produced on a large scale by distillation of the leaves and young shoots of both the bitter and sweet varieties of orange (see p. 1025), the former being far the more fragrant and valuable. The leaves of the bitter orange are obtained in the Mediterranean lemon-districts, where lemons are mostly grafted on orange-stocks; the latter put forth shoots during the summer, which are often allowed to grow to a length of some feet, and are then cut off, bound in bundles, and conveyed to the distillery. The oil is very extensively employed in perfumery. Other *Citrus*-oils are described under Bergamot, Cedrat, Lemon, Neroli, and Orange (pp. 1417, 1419, 1423, 1425).

Pimento.—See Allspice, p. 1416.

Pine-oils.—An essential oil is distilled at Reichenhall, in Bavaria, and other places, from the leaves and twigs of *Pinus Pumilio*, which is much esteemed in medicine by the Germans. That from *P. sylvestris* is also recommended in certain throat diseases. (See also Turpentine-oil, p. 1431).

Poplar-oil.—The leaf-buds of *Populus nigra*, and other species, by aqueous distillation, give a colourless oil, of pleasant, balsamic odour.

Pyrethrum-oil.—The flowering herb of *Chrysanthemum* [*Pyrethrum*] *Parthenium*, subjected to aqueous distillation, affords a greenish oil, depositing stearoptene by keeping.

Rose-oil, or Otto [Attar] of Roses (Fr., *Essence de Roses*; Ger., *Rosenöl*).—This celebrated perfume is the volatile essential oil distilled from the flowers of some varieties of rose. The botany of roses appears to be in a transition and somewhat unsatisfactory state. Thus the otto-yielding rose is variously styled *Rosa damascena*, *R. sempervirens*, *R. moschata*, *R. gallica*, *R. centifolia*, *R. provincialis*. It is pretty generally agreed that the kind grown for its otto in Bulgaria is the damask-rose (*R. damascena*), a variety induced by long cultivation, as it is not to be found wild. It forms a bush, usually 3–4 ft., but sometimes 6 ft. high; its flowers are of moderate size, semi-double, and arranged several on a branch, though not in clusters or bunches. In colour, they are mostly light-red; some few are white, and said to be less productive of otto.

The utilization of the delicious perfume of the rose was attempted, with more or less success, long prior to the comparatively modern process of distilling its essential oil. The early methods chiefly in vogue were the distillation of rose-water, and the infusion of roses in olive-oil, the latter flourishing in Europe generally down to the last century, and surviving at the present day in S. France. The butyraceous oil produced by the distillation of roses for making rose-water in this country is valueless as a perfume; and the real otto was scarcely known in British commerce before the present century.

The profitable cultivation of roses for the preparation of otto is limited chiefly by climatic conditions. The odoriferous constituent of the otto is a liquid containing oxygen, the solid hydrocarbon or stearoptene, with which it is combined, being absolutely devoid of perfume. The proportion which this inodorous solid constituent bears to the liquid perfume increases with the unsuitability of the climate, varying from about 18 per cent. in Bulgarian oil, to 35 and even 68 per cent. in rose-oils distilled in France and England. This increase in the proportion of stearoptene is also shown by the progressively heightened fusing-point of rose-oils from different sources: thus, while Bulgarian oil fuses at about 16°–18° (61°–64° F.), an Indian sample required 20° (68° F.); one from S. France, 21°–23° (70°–73° F.); one from Paris, 29° (84° F.); and one obtained in making rose-water in London, 30°–32° (86°–89½° F.). Even in the Bulgarian oil, a notable difference is observed between that produced on the hills, and that from the lowlands.

It is, therefore, not surprising that the culture of roses, and extraction of their perfume, should have originated in the East. Persia produced rose-water at an early date, and the town of Nisibin, north-west of Mosul, was famous for it in the 14th century. Shiraz, in the 17th century, prepared both rose-water and otto, for export to other parts of Persia, as well as all over India. The Perso-Indian trade in rose-oil, which continued to possess considerable importance in the third quarter of the 18th century, is declining, and has nearly disappeared; but the shipments of rose-water still maintain a respectable figure. The value, in rupees, of the exports of rose-water from Bushire in 1879, were—4000 to India, 1500 to Java, 200 to Aden and the Red Sea, 1000 to Muscat and Dependencies, 200 to Arab coast of Persian Gulf, and Bahrein, 200 to Persian coast and Mekran, and 1000 to Zanzibar. Similar statistics relating to Lingah, in the same year, show—otto: 400 to Arab coast of Persian Gulf and Bahrein; and 250 to Persian coast and Mekran. And Bahrein—Persian otto: 2200 to Koweit, Busrah, and Bagdad; rose-water: 200 to Arab coast of Persian Gulf, and 1000 to Koweit, Busrah, and Bagdad.

India itself has a considerable area devoted to rose-gardens, as at Ghazipur, Lahore, Amritzur, and other places, the kind of rose being *R. damascena*, according to Brandis. Both rose-water and otto are produced. The flowers are distilled with double their weight of water in clay stills; the rose-water (*goolabi pani*) thus obtained is placed in shallow vessels, covered with moist muslin to keep out dust and flies, and exposed all night to the cool air, or fanned. In the morning, the film of oil, which has collected on the top, is skimmed off by a feather, and transferred to a small phial. This is repeated for several nights, till almost the whole of the oil has separated. The quantity of the product varies much, and three different authorities give the following figures:—(*a*) 20,000 roses to make 1 rupee's weight (176 gr.) of otto; (*b*) 200,000 to make the same weight; (*c*) 1000 roses afford less than 2 gr. of otto. The colour ranges from green to bright-amber and reddish. The oil (otto) is most carefully bottled; the receptacles are hermetically sealed with wax, and exposed to the full glare of the sun for several days. Rose-water deprived of otto is esteemed much inferior to that which has not been so treated. When bottled, it is also exposed to the sun for a fortnight at least.

The Mediterranean countries of Africa enter but feebly into this industry, and it is a little remarkable that the French have not cultivated it in Algeria. Egypt's demand for rose-water and rose-vinegar is supplied from Medinet Fayum, south-west of Cairo. Tunis has also some local reputation for similar products. Von Maltzan says that the rose there grown for otto is the dog-rose (*R. canina*), and that it is extremely fragrant, 20 lb. of the flowers yielding about 1 dr. of otto. Genoa occasionally imports a little of this product, which is of excellent quality. In S. France, rose-gardens occupy a large share of attention, about Grasse, Cannes, and Nice; they chiefly produce rose-water, much of which is exported to England. The essence (otto) obtained by the distillation of the Provence rose (*R. provincialis*) has a characteristic perfume, arising, it is believed, from the bees transporting the pollen of the orange-flowers into the petals of the roses. The French otto is richer in stearoptene than the Turkish, 9 *grm.* crystallizing in a *litre* (1¾ pint) of alcohol at the same temperature as 18 *grm.* of the Turkish. The best preparations are made at Cannes and Grasse. The flowers are not there treated for the otto, but are submitted to a process of maceration in fat or oil, 10 *kilo.* of roses being required to impregnate 1 *kilo.* of fat. The price of the roses varies from 50 *c.* to 1 *fr.* 25 *c.* per *kilo.*

But the one commercially important source of otto of roses is a circumscribed patch of ancient Thrace or modern Bulgaria, stretching along the S. slopes of the central Balkans, and approximately included between the 25th and 26th degrees of E. longitude, and the 42nd and 43rd degrees of N. latitude. The chief rose-growing districts are Philippopli, Chirpan, Giopcu, Karadshah-Dagh, Kojun-Tepe, Eski-Sara, Jeni-Sara, Bazardshik, and the centre and headquarters of the industry, Kazanlik (Kisanlik), situated in a beautiful undulating plain, in the valley of the Tunja. The productiveness of the last-mentioned district may be judged from the fact that, of the 123 Thracian localities carrying on the preparation of otto in 1877—they numbered 140 in 1850—42 belong to it. The only place affording otto on the N. side of the Balkans is Travina. The geological formation throughout is essentially syenite, the decomposition of which has provided a soil so fertile as to need but little manuring. The vegetation, according to Baur, indicates a climate differing but slightly from that of the Black Forest, the average summer temperatures being stated at 28° (82° F.) at noon, and 20° (68° F.) in the evening. The rose-bushes flourish best and live longest on sandy, sun-exposed (S. and S.-E. aspect) slopes. The flowers produced by those growing on inclined ground are dearer and more esteemed than any raised on level land, being 50 per cent. richer in oil, and that of a stronger quality. This proves the advantage of thorough drainage. On the other hand, plantations at high altitudes yield less oil, which is of a character that readily congeals, from an insufficiency of summer heat. The districts lying adjacent to and in the mountains are sometimes visited by hard frosts, which destroy or greatly reduce the crop.

Floods also occasionally do considerable damage. The bushes are attacked at intervals and in patches by a blight similar to that which injures the vines of the country.

The bushes are planted in hedge-like rows in gardens and fields, at convenient distances apart, for the gathering of the crop. They are seldom manured. The planting takes place in spring and autumn; the flowers attain perfection in April–May, and the harvest lasts from May till the beginning of June. The expanded flowers are gathered before sunrise, often with the calyx attached; such as are not required for immediate distillation are spread out in cellars, but all are treated within the day on which they are plucked. Baur states that, if the buds develop slowly, by reason of cool damp weather, and are not much exposed to sun-heat when about to be collected, a rich yield of otto having a low solidifying-point, is the result; whereas, should the sky be clear and the temperature high at or shortly before the time of gathering, the product is diminished, and is more easily congealable. Hanbury, on the contrary, when distilling roses in London, noticed that, when they had been collected on fine dry days, the rose-water had most volatile oil floating upon it, and that, when gathered in cool rainy weather, little or no volatile oil separated.

The flowers are not salted, nor subjected to any other treatment, before being conveyed in baskets, on the heads of men and women, and backs of animals, to the distilling apparatus. This consists of a tinned-copper still, erected on a semicircle of bricks, and heated by a wood fire; from the top, passes a straight tin pipe, which obliquely traverses a tub kept constantly filled with cold water, by a spout from some convenient rivulet, and constitutes the condenser. Several such stills are usually placed together, often beneath the shade of a large tree. The still is charged with 25–50 lb. of roses, not previously deprived of their calyces, and double the volume of spring water. The distillation is carried on for about 1½ hour, the result being simply a very oily rose-water (*ghyul-suyu*). The exhausted flowers are removed from the still, and the decoction is used for the next distillation, instead of fresh water. The first distillates from each apparatus are mixed and distilled by themselves, one-sixth being drawn off; the residue replaces spring water for subsequent operations. The distillate is received in long-necked bottles, holding about 1¼ gal. It is kept in them for a day or two, at a temperature exceeding 15° (59° F.), by which time, most of the oil, fluid and bright, will have reached the surface. It is skimmed off by a small, long-handled, fine-orificed tin funnel, and is then ready for sale. The last-run rose-water is extremely fragrant, and is much prized locally for culinary and medicinal purposes. The quantity and quality of the otto are much influenced by the character of the water used in distilling. When hard spring water is employed, the otto is rich in stearoptene, but less transparent and fragrant. The average quantity of the product is estimated by Baur at 0·037–0·040 per cent.; another authority says that 3200 *kilo.* of roses give 1 *kilo.* of oil.

Pure otto, carefully distilled, is at first colourless, but speedily becomes yellowish; its sp. gr. is 0·87 at 22½° (72½° F.); its boiling-point is 229° (444° F.); it solidifies at 11°–16° (52°–61° F.), or still higher; it is soluble in absolute alcohol, and in acetic acid. The most usual and reliable tests of the quality of an otto are (1) its odour, (2) its congealing-point, (3) its crystallization. The odour can be judged only after long experience. A good oil should congeal well in five minutes at a temperature of 12½° (54½° F.); fraudulent additions lower the congealing-point. The crystals of rose-stearoptene are light, feathery, shining plates, filling the whole liquid. Almost the only material used for artificially heightening the apparent proportion of stearoptene is said to be spermaceti, which is easily recognizable from its liability to settle down in a solid cake, and from its melting at 50° (122° F.)., whereas stearoptene fuses at 33° (91½ F°.). Possibly paraffin-wax (see Paraffin) would more easily escape detection.

The adulterations by means of other essential oils are much more difficult of discovery, and much more general; in fact, it is said that none of the Bulgarian otto is completely free from this kind of sophistication. The oils employed for the purpose are certain of the grass oils (*Andropogon* and *Cymbopogon spp.*), notably that afforded by *Andropogon Schœnanthus* (see Ginger-grass-oil, p. 1422), called *idris-yaghi* by the Turks, and commonly known to Europeans as " geranium-oil," though quite distinct from true geranium-oil. The addition is generally made by sprinkling it upon the rose-leaves before distilling. It is largely produced in the neighbourhood of Delhi, and exported to Turkey by way of Arabia; it is sold by Arabs in Constantinople in large, bladder-shaped, tinned-copper vessels, holding about 120 lb. As it is usually itself adulterated with some fatty oil, it needs to undergo purification before use. This is effected in the following manner:—The crude oil is repeatedly shaken up with water acidulated with lemon-juice, from which it is poured off after standing for a day. The washed oil is placed in shallow saucers, well exposed to sun and air, by which it gradually loses its objectionable odour. Spring and early summer are the best seasons for the operation, which occupies 2–4 weeks, according to the state of the weather, and the quality of the oil. The general characters of this oil are so similar to those of otto of roses—even the odour bearing a distant resemblance,—that their discrimination when mixed is a matter of practical impossibility. The ratio of the adulteration varies from a small figure up to 80–90 per cent. The only safeguard against deception is to pay a fair price, and to deal with firms of good repute.

The otto is put up in squat-shaped flasks of tinned copper, called *kunkumas*, holding 1–10 lb., and sewn up in white woollen cloths. Usually their contents are transferred at Constantinople into small gilded bottles of German manufacture, for export. The Bulgarian otto-harvest, during the five years 1867–71, was reckoned to average somewhat below 400,000 *meticals*, *miskals*, or *midkals* (of about 3 dwt. troy), or 4226 lb. av.; that of 1873, which was good, was estimated at 500,000, value about 700,000*l.* The harvest of 1880 realized more than 1,000,000*l.*, though the roses themselves were not so valuable as in 1876. About 300,000 *meticals* of otto, valued at 932,077*l.*, were exported in 1876 from Philippopolis, chiefly to France, Australia, America, and Germany.

Rosemary-oils.—The common rosemary (*Rosmarinus officinalis*) is a native of S. Europe and Asia Minor, growing abundantly wild in Spain, France, Germany, and Austro-Hungary, and under cultivation to a small extent at Mitcham, in Surrey. The cultivation resembles that of lavender, except that the plant requires longer to mature. The otto produced in England is valued at 10 times the price of Continental articles, but its quantity is so inconsiderable that it scarcely forms a commercial article. The market is chiefly supplied from plants growing wild in S. France, and Italy, as well as on the islands of Lesina, Maslinica, and Lissa, off the Dalmatian coast, where the peasants annually retort some 20,000 *funti* (of 1·2 lb.), and export 300–350 *quintals* of the oil viâ Trieste. In France and Italy, the plant is gathered in summer, but not while in flower; generally the entire herb is distilled, but sometimes the flowering tops only are selected for the operation. In Dalmatia, the biennial shoots are cut in May, sun-dried for about 8 days, and deprived of their leaves. The latter are then moistened with water, and treated in copper stills over naked fires. The yield from 1 cwt. of fresh herb is about 24 oz. of oil, but is subject to great variation. The oil is colourless or yellowish, with a somewhat camphor-like odour and flavour of the herb; sp. gr. 0·886–0·933; dissolves readily in alcohol. It has a very wide use in perfumery. Trieste supplies 34,000–40,000 lb. annually of the oil to Europe and America.

The so-called "wild rosemary" or "Labrador tea," *Ledum palustre* (see Narcotics—*Ledum*, p. 1308), gives an essential oil by aqueous distillation.

Rosewood- or Rhodium-oil.—By aqueous distillation, the root and stem of *Convolvulus scoparius* and *C. floridus*, growing in the Canaries, afford an essential oil, in the proportion of about 3 oz. from 1 cwt. The oil is thin, pale-yellow, with an odour of roses and cubebs, and a bitter aromatic flavour. It has disappeared from commerce, and is completely replaced in perfumery by an artificial compound.

Rue-oil.—The whole herb of *Ruta graveolens*, submitted to aqueous distillation, affords a colourless oil (about 1 lb. from 150–200 lb.), with strong odour and flavour of the herb, sp. gr. 0·831, congealing at −1°– −2° (30¼°–28½° F.), and boiling at 228°–230° (442½°–446° F.). It is principally employed in aromatic vinegars (see p. 335).

Saffron-oil.—The stigmata of *Crocus sativus* (see Dyestuffs—Saffron, p. 866), by aqueous distillation, yield a thin yellow oil, with an odour of saffron, which is slowly converted into a solid mass that sinks in water.

Sagapenum-oil.—By distilling sagapenum (see Resinous Substances—Sagapenum) with water, it affords a thin, yellow oil, with a garlic-like odour at first, then becoming turpentinous, drying to a translucid varnish, and dissolving readily in alcohol.

Sage-oil.—The whole herb of sage (*Salvia officinalis*), by aqueous distillation, yields a greenish-yellow oil, with the odour and flavour of the herb, sp. gr. 0·864, boiling at 130°–160° (266°–320° F.) It is rarely employed, but is a useful perfume. The plant grows both wild and cultivated around Grasse (S. France), and yields 1 lb. of oil from 300 lb.

Sandal-wood-oil.—The essential oil which carries the delightful perfume of sandal-wood (see Perfumes—Sandal-wood) is extracted in Mysore in the following manner. The roots yield the largest quantity and finest quality, and next in value is the dark central wood of the tree. The chips and billets are distilled with water in a large globular clay pot, with an open mouth, about 2½ ft. deep, and 6½ ft. in circumference at the bilge. When charged, the mouth of the still is closed with a clay lid, having a small central hole, through which is passed a bent copper tube, about 5½ ft. long, for the escape of the vapour. The lower end of this tube is carried into an ordinary crude condenser. The white or sap wood is rejected for distilling. The operation is carried on for 10 days and nights, the water being occasionally renewed from the heated overflow of the condenser. The yield from good wood is at the rate of 2½ per cent.; European distillers do not succeed in getting more than 30 oz. from 1 cwt. The oil is transparent, of pale-yellow colour, resinous flavour, sweet peculiar odour, sp. gr. 0·980. It is in great request as a perfume.

Sassafras-oils.—Essential oils are obtained from the root-wood and root-bark of *Sassafras officinale* (see Drugs—Sassafras, p. 823). These oils are largely distilled in America. The charge of a still, about 11 bush. of chips, yield 1–5 lb. of oil, according to the quality of the root, and the proportion of bark present. The wood of the root gives 1–2 per cent., while the bark of it affords double that amount, and the stem and leaves of the tree yield scarcely any. The commercial oil is derived entirely from America, the quantity annually produced in Baltimore, the chief market for a radius of 300 miles, being 15,000–20,000 lb.; it was 20,200 lb. in 1876. The oil is colourless, yellow, or reddish-brown, according to the character of the root used; it has the odour of sassafras, and sp. gr. 1·087–1·094. When cooled, it deposits crystals of sassafras-camphor (see p. 578). It is used in America to give a pleasant flavour to drinks, tobacco, and soaps.

Australian sassafras (*Atherosperma moschatum*), growing abundantly in gullies near the coast in Victoria and Tasmania, gives a thin, unctuous, pale-yellow oil by aqueous distillation of the bark; its odour resembles sassafras and caraway, with a bitter aromatic flavour, sp. gr. 1·04, boiling at 230°–245° (446°–473° F.)

Savin-oil.—The branchlets and fruits of *Juniperus Sabina*, distilled with water, yield a colourless oil, with strong odour and flavour of the shrub, sp. gr. 0·89–0·94, boiling at 155°–161° (311°–322° F.). In S. France, 1 lb. of oil is obtained from 300–400 lb. The yield from young branches is 1·30 per cent. fresh, and 2·5 per cent. dry; from the fresh berries, 10 per cent. The oil is used medicinally, and is often adulterated with turpentine-oil.

Other *Juniperus*-oils are described under Cedar and Juniper (pp. 1419, 1422).

Spearmint-oil.—The common garden mint or spearmint (*Mentha viridis*) is a fragrant perennial cultivated plant of Europe, Asia, and N. America. It is cultivated in the United States in the same manner as peppermint (see p. 1425). H. G. Hotchkiss, of Lyons, Wayne Co., New York, makes some 1000 lb. of the essential oil annually. Its sp. gr. is 0·91–0·93.

Spike-oil.—See Lavender-oil (p. 1423).

Sweet-flag-oil.—The rhizome of *Acorus Calamus* (see p. 190), when distilled with water, affords a pale- to dark-yellow oil, with strong penetrating odour of the root, aromatic, bitter, burning, camphoraceous flavour, sp. gr. 0·89–0·98, dissolving readily in alcohol, and boiling at 195° (383° F.)

Tansy-oil.—The herb and flowers of *Tanacetum vulgare*, distilled with water, yield a thin yellow oil, having the specific odour of the plant.

Tarragon-oil.—The leaves of *Artemisia Dracunculus*, distilled with water, give an oil of 0·935 sp. gr., boiling at 200°–206° (392°–403° F.). The plant is cultivated on a large scale near Grasse (S. France), yielding two crops yearly (July and October); its yield of oil is 1 lb. from 300–500 lb., according to season and locality.

Other *Artemisia*-oils are described under Mugwort, Wormseed, and Wormwood (pp. 1424, 1432).

Tea-oil.—An essential oil is extracted from tea-leaves by distilling with water, shaking the distillate with ether, pouring off the ether solution, and evaporating; it is lemon-yellow, of strongly narcotic, tea-like odour and flavour, and solidifies on keeping. It is not to be confounded with the fatty oil extracted from the seed (see p. 1411).

Thyme-oil.—All varieties of the thyme afford fragrant essential oils, but this is especially the case with the wild or lemon-thyme (*Thymus Serpyllum*). The cultivated variety (*T. citriodorus*) of this species is not utilized by perfumers; its oil is golden-yellow, with a pleasant odour of lemon and thyme, and an aromatic, bitter flavour; sp. gr. 0·89–0·91. The species cultivated for the sake of its odour is the common or garden-thyme (*T. vulgaris*). This plant is extremely abundant on the arid wastes of Languedoc; it is collected from the rocky hills in the department of Gard, S. France, and distilled chiefly in the villages around Nîmes. The entire herb is used, and the process is carried on both in May–June, when the plant is in flower, and again in the autumn. The yield is about 1 per cent. of oil; this is deep reddish-brown, becoming colourless but slightly less fragrant on re-distillation. Both the former (*huile rouge de thym*) and the latter (*h. blanche de t.*) are met with in commerce. Some 11,938 lb. of thyme-oil were consumed in England in 1839, and 7553 lb. in 1844. The oil is used medicinally (chiefly veterinary), and in perfumery under the name of "origanum" (see p. 1424); one of its constituents, thymol, is a valued disinfectant. It is often adulterated with oil of turpentine, or fraudulently deprived of its thymol before sale.

Turpentine-oil.—A volatile oil pervades all parts of the numerous species of *Pinus* (see Timber), and is mostly obtained from the resinous exudations (see Resinous Substances) by dry or aqueous distillation. The commercial oils are commonly distinguished as:—"French," from *P. maritima* and *P. Pinaster*; "German," from *P. sylvestris*, *Abies pectinata*, and *A. excelsa*; "Venetian," from *Larix europæa*; and "English," from *P. Tæda* and *P. australis*. They are thin, colourless, with strong specific odour and flavour, sp. gr. 0·850–0·880, boil at 150°–160° (302°–320° F.), scarcely soluble in water, sparingly in alcohol, readily in ether.

Fatty oils from *Pinus spp.* are described on p. 1408.

Valerian-oil.—By aqueous distillation, the root of *Valeriana officinalis* (see Drugs, p. 826) gives a thin, neutral, yellowish oil, with an odour of the dried root, sp. gr. 0·90–0·96, readily soluble in alcohol.

Wintergreen-oil.—All parts of *Gaultheria procumbens*, a little creeping plant of N. United States and Canada, possess a pleasant aromatic odour and flavour, due to the presence of an essential oil. The leaves are submitted to aqueous distillation in a copper vessel (tin-plate is better, and wood probably would be found even more satisfactory), the water being used repeatedly. The yield is about 0·66–0·80 per cent. According to the latest returns, 828 lb. of this oil was distilled in the United States. It is pale-green, of the same composition as birch-bark-oil (see p. 1417), sp. gr. 1·17, and is employed medicinally. It is sometimes adulterated with sassafras-oil and chloroform in large proportion.

In Java, *G. punctata* and *G. leucocarpa* are abundant on the tops of many of the volcanoes, and their leaves yield oils scarcely distinguishable from the Canadian wintergreen-oil: the proportion from the former is 340 grm. of oil from 59 lb. of fresh leaves, or about 1·15 per cent.; and from the latter, 40 grm. from 65 lb., or 0·012 per cent.

Andromeda Leschenaultii, common hill-plant in Ceylon; oil closely resembling Canadian wintergreen, but containing less of the peculiar hydrocarbon oil found in the Canadian product, and therefore superior, but the commercial demand would hardly repay its preparation.

Wormseed- and Wormwood-oils.—The flowers of *Artemisia Cana* and *A. Lippii*, by aqueous distillation, yield a colourless or yellowish oil, with an odour of the drug, an acrid, burning, aromatic flavour, sp. gr. 0·925–0·945, boiling at 175° (347° F.) after rectification. The leaves and flowers of *A. Absinthium*, by aqueous distillation, give a dark-green oil, with odour and flavour of the plant, sp. gr. 0·973, boiling at 205° (401° F.), and readily soluble in alcohol. The United States produced 170 lb. of this oil, according to the latest returns.

Other *Artemisia*-oils are described under Mugwort and Tarragon (pp. 1424, 1431); see also Drugs—Wormseed, p. 826.

Miscellaneous.—The following plants have been ascertained to afford volatile oils, exhibiting the properties stated:—

Aristolochia Serpentaria, root: light-brown; with odour and flavour of valerian and camphor.

Arnica montana (see Drugs, p. 793), flowers and root: former blue or brownish-green, latter brownish-yellow.

Asarum europœum, root: thickish; yellowish; valerian-like odour; burning acrid flavour.

Backhousia citriodora: in forest tracts of S. Queensland; the lemon-scented leaves deserve distillation.

Bursera gummifera, resin (see Resinous Substances—Gomart): resembles turpentine-oil.

Carapa guianensis (see Crab-oil, p. 1386): unctuous; colourless; very bitter flavour; solid at 4° (39° F.).

Chenopodium ambrosioides, herb: pale- to greenish-yellow, colourless when rectified; very thin; great light-refracting power; strong odour of the herb; aromatic peppermint-like flavour; sp. gr. 0·902; boils at 179°–181° (354°–358° F.); readily soluble in alcohol.

Cochlearia officinalis, C. Danica, and *C. Anglica*, herb: sp. gr. 0·942; with pungently acrid odour and flavour of the green herb in the highest degree.

Curcuma longa, root: thin; citron-yellow; penetrating odour and hot flavour.

C. Zedoaria, tubers: pale-yellow; turbid; thick; peculiar, fragrant, camphor-like odour; bitter, hot, camphoraceous flavour.

Dahlia purpurea, tubers: yellowish; strong odour of the tubers; sweetish, sub-acrid flavour; becomes thick like butter.

Daucus Carota, root: peculiar, strong, penetrating odour; similar, warming, disagreeable flavour; sp. gr. 0·886.

Eriostemon squameum, leaves: pale-yellow; similar but milder odour and flavour than rue.

Hedwigia balsamifera, balsam: yellow; pleasant turpentinous odour; hot flavour.

Lycopus europœus, herb: green; butter-like; odour of the herb; acrid flavour.

Mercurialis annua, dried herb: thickish consistence.

Nigella sativa (see also p. 1415), seeds: colourless, with bluish fluorescence; mixed odour of fennel and bitter almonds.

Oenanthe Phellandrium, fruits: yellowish to brownish; thin; penetrating odour and flavour of the fruit; sp. gr. 0·852.

Osmitopsis asteriscoides, flowers: thin; yellowish, rectified colourless; penetrating odour of camphor and cajuput; burning, rancid flavour; readily soluble in alcohol; sp. gr. 0·921; boiling-point, 178° (352½° F.).

Pastinaca sativa, fruits: clear, colourless; not unpleasant odour; aromatic flavour; sp. gr. 0·8672 at 17½° (63½° F.).

Peucedanum Oreoselinum and *P. ostruthium*, herb of former: strong, aromatic, juniper-like odour; sp. gr. 0·840; boiling-point, 163° (325½° F.). Root of latter: thin; colourless to pale-yellow; penetrating odour; warm, camphoraceous flavour.

Philadelphus coronarius, flowers: by ether; golden-yellow; narcotic in quantity; delightful odour when diffused.

Pittosporum undulatum, flowers: limpid; colourless; extremely agreeable jasmine-like odour; disagreeably hot and bitter flavour.

Prostanthera Lasianthos, and *P. rotundifolia*, leaves: former, greenish-yellow; mint-like odour and flavour; sp. gr. 0·912. Latter, of darker colour; and 0·941 sp. gr.

Ravenala sp., of Madagascar, and *R. amazonica*, in Guiana: blue pulpy aril surrounding the seeds.

Thuya occidentalis, the green parts: colourless to greenish-yellow; camphoraceous odour and flavour; sp. gr. 0·925; boiling-point, 190°–197° (374°–386½° F.); readily soluble in alcohol.

Tropæolum majus, fruits: yellow; peculiar, aromatic odour; acrid, burning flavour; inflames the skin more than mustard-oil; contains sulphur; boils at 120°–130° (248°–266° F.).

Zieria Smithii, leaves: pale-yellow; odour and flavour of rue; sp. gr. 0·950.

MINERAL OILS.

Mineral oils include the following products:—Peat-oils, or the hydrocarbons which may be distilled from peat; shale-oils, or similar bodies obtainable from bituminous shales; coal-tar-oils, or allied products of the distillation of the tar obtained in making illuminating-gas; and, most important by far, the large series of petroleums or rock-oils found ready-formed in certain geological strata in many parts of the world.

Peat-oils.—Before the introduction of American petroleum, the distillation of oils from peat was a remunerative industry in this country; but where petroleum, bituminous shale, or oil-coal can be had in abundance, the profitable utilization of peat-oil in this manner is impossible in the present state of our knowledge and appliances. Of the bog-peats formerly distilled by the Irish Peat Co., 100 ton, in close retorts, gave 2 ton 15 cwt. of tar, yielding 409 gal. of refined oils and paraffin; by kiln treatment, 2 ton 8 cwt. of tar, affording 304 gal. of oils and paraffin. Dense mountain peat from Antrim, in Dr. Hodge's experiments with 50 tons, produced at the rate of 4·44 per cent. of tar. The very dense bituminous peat cut by Sir James Matheson, in Lewis, one of the Hebrides, returns, from 100 tons, air-dried, by close retort, 2097 gal. of tar, equivalent to 1629 gal. of crude oil, 999 gal. of which may be secured in the refined state. This was highly profitable when the oil sold at 2*s.* a gal., but the production of oil has long been discontinued even here, and the tar is used in the ship-yards.

Shale-oils.—Beds of dark, coaly-looking mineral, known as "bituminous" or "bituminiferous" shales, occur in this country in the Tertiary, Cretaceous, Oolitic, Triassic, and Carboniferous formations. These vary in quality and aspect, according to the proportion of mineralized organic matter present, ranging from a mere argillaceous mineral almost to coal. The beds vary in thickness and in character; they are interstratified with sandstones, limestones, coals, &c.; and are mined much in the same way as coal. Many of the Oolitic and Wealden shales, though valuable for some purposes, are useless as sources of illuminating-oils, and it is those of the Carboniferous system that are chiefly distilled for the production of paraffin and paraffin-oils. Bituminous shales occur in most British coal-fields. Their production in 1880 was as follows:—

The shales of the lower coal-measures of Linlithgow, Lanark, Ayr, Fife, and Midlothian are those most largely raised for distilling. Superior shales are recognized by their lightness and toughness, or "boardiness," in mining phraseology, and by their brown streak. Those in use yield a quantity of crude oil varying from 18 to 80 gal. a ton. This branch of manufacture is discussed at length in the article on Paraffin.

An earthy lignite occurring within a small portion of the Saxon Thuringian brown-coal formation, between Weissenfels and Zeitz, forms the material for a large mineral oil and paraffin industry, dealing with some 36,000 tons of tar annually, and producing about 12,500 tons of paraffin-oils, 6000 tons of gas- and lubricating-oils, 5000 tons of paraffin, and 3600 tons of accessory products. This lignite contains nests and branches of a fusible hydrocarbon (pyropissite), yielding as much as 66 per cent. of tar on distillation.

Coal-tar-oils.—The extraction and utilization of the oils contained in coal-tar will be found fully described and illustrated in the article on Coal-tar Products, pp. 641–684.

Petroleum, Rock-oil, Naphtha, or Mineral Tar (Fr., *Bitume liquide*; Ger., *Erdöl, Steinöl*).—These names are applied with little discrimination to a class of liquids occurring in various geological formations and geographical localities; possessing a more or less limpid, oily consistence, a strong bituminous odour, a usually dark yellowish-brown colour, a sp. gr. ranging from 0·8 to 1·1; and composed of hydrocarbons varying in constitution and boiling-point in almost every case, as will be noticed further on. Very closely allied products are asphalte or native bitumen (see p. 341), and ozokerit or earth-wax (see Wax—Ozokerit).

Origin and Occurrence.—The origin of petroleum has been a subject of much speculation among geologists. The most widely accepted notion is that it is due to the very slow decomposition of organic remains, animal, vegetable, or both combined. But the occurrence of any organic detritus in such formations as the Silurian, in sufficient quantity to account for the enormous yield of oil, is doubted by many. Another attempted explanation of its origin is the percolation of sea-water to depths where the temperature is sufficiently high, in contact with such minerals as iron and its sulphides, to form carburets, in support of which is adduced the frequent occurrence of petroleum and similar products as accompaniments of volcanic action. A third plausible argument refers the formation of all the members of this hydrocarbon series to the condensation of carbon vapours escaping from a depth in the earth on meeting with hydrogen combined as water, the new compound becoming condensed to various degrees according to local circumstances. Reflecting on the vast geological distribution of petroleum, it is only reasonable to suppose that more than one cause has been instrumental in its production. All experience hitherto gained tends to prove that, though in a few unimportant cases, the creative agency, whatever it may be, seems to be still at work, yet in the great majority of instances, the active formation of the article is a work of the far past, and that we are recklessly exhausting the supplies which have been countless ages in course of collection.

Petroleum is found in strata of almost all ages, from Silurian upwards. In Canada, it occurs mainly in the corniferous limestone of the Lower Devonian, also more or less in the bird's-eye limestone of the Lower Silurian, and the Lower Helderberg limestone of the Upper Silurian. In the United States, it is obtained chiefly from Devonian and Carboniferous formations; in S. California, from Tertiary shales; in Trinidad, from Tertiary lignites; in Persia and the Caspian region, from Tertiary shales and limestones; in Burma, from shallow Tertiary and Post-tertiary clays and lignites.

Commercial Sources.—Petroleum has been discovered in W. Staffordshire and in Scotland. It is obtained at Bechelbronn and Schwabwiller, Department of Bas-Rhin, France. Germany possesses petroleum-springs affording a limited quantity near Lüneburg, in Alsace; borings are being made in the district S. of Celle, in Hanover, where those reaching 60 ft. in depth are yielding 4 cwt. of oil daily, of improving quality; and an experimental sinking near Heide, in Holstein, has struck a flowing well giving a superior product. The oil-wells of Italy number about 5, situated in the Valley of Cocco, in the Abruzzi, and at Riva-Nazzano, near Voghera, in Piedmont. The exploitation has been on a primitive scale hitherto, and the production trifling.

The resources of the previously-cited localities appear insignificant in comparison with those of a portion of E. Europe embracing parts of Hungary, Galicia, Bukowina, Roumania, and Moldavia. Dr. H. Gintl, a great authority in these matters, considers this petroleum (and ozokerit) region uniform in origin and history with the similar formation in the Caspian and Trans-Caucasian countries. He declares that the whole N. flank of the Carpathians, from Librautowa, in Neu-Sandezer, to Sloboda, in Kolomea'er, or a length of over 270 miles, will be found to yield petroleum and ozokerit; some 13,500 wells in about 126 localities, give a yearly yield of about 520,000 *centners* (of 110¼ lb.) of petroleum, and 360,000 *centners* of ozokerit, representing a capital of about 600,000*l.* There are 9 districts of Galicia where petroleum is obtained, the principal being Boryslav, where are situated 3200 of the 4000–5000 wells now being worked. The ground is divided into very small lots, of different ownership; the wells are sunk very near together, and, in this district, to very shallow depths, 18–25 fathoms being the average, and 65 fathoms the maximum. In 1873, Boryslav produced 200,000 cwt. of crude petroleum, and Wolanka, 20,000 cwt.; the total value (including a larger quantity of ozokerit) was 462,000*l.*, and the total labour employed was 9000. The common method of working is to sink a shaft down to the stratum of plastic clay; with favourable soil and little water, the sides are lined with 2-in. boards; so far as the clay extends, the only lining used is wicker-work. The ordinary dimensions of the shafts are 26 in. × 32–37 in., and 20 in. × 36 in. when lined with wicker. The sinking is always carried on with the aid of ventilators and air-tubes; no light is admitted, except while cutting through ozokerit, when a safety-lamp is used. Large quantities of gas are always present in the workings. The petroleum is usually met with at a shallower level than the ozokerit. When oil is struck, operations are temporarily suspended. The pit is covered with boards, so that the well may not cool, and the oil is then extracted by a crude arrangement of buckets and winding apparatus. The average daily yield of a well is 30 gal., but some give 140 gal. When the flow stops, the well is usually deepened, so as to obtain a second supply. Between the marl strata and sandstone strata, are often deposits of ozokerit, whose working will be described in another article (see Wax—Ozokerit). In the district of Bóbrka, which, according to Dr. Gintl, is by far the most advanced, the petroleum is found in a conglomerate containing rounded quartz particles as large as lentils, the whole being a porous mass perfectly free from lime, and emitting much smoke and a strong odour of petroleum when burned. Wells sunk 66 ft. have produced 3000 cwt. of petroleum monthly for a considerable time. The depth first driven does not exceed 50–200 ft., but as the yield decreases, they are deepened to 800–1000 ft. This is the only district where anything like the American system has been introduced. Boring-rods making a 6-in. or 7-in. hole are used, and generally worked by steam. The petroleum is drawn off by 2-in. tubes. A rule obtains that where ozokerit occurs, there petroleum also will be found; but the converse does not hold. The wells are far less productive than those of America, though the latter do not yield ozokerit. The petroleum obtained is distilled in the ordinary way, so as to afford a good burning-oil.

Petroleum has been known in Roumania and Moldavia for at least 50 years, and was collected by the peasants for use as wagon-grease, and in medicine. It was first distilled to produce a lighting-oil in 1857–8, and was sent into commerce both by rail and by the Danube. The Roumanian petroleum-field lies on the southern slopes of the Transylvanian Carpathians, from Kolibas to Rimnik Sarat, the most important points being Kolibas, Baikoiu, Pukureti, Tintea, Duftinesti, Sarate, and Rimnik Sarat. All these occur in the Miocene. The largest and deepest wells are in Sarate, and give some 3500 barrels yearly. The wells of Sarate, Kolibas, Pukureti, Duftinesti, and Tintea, lie only 10–18 *kilom.* from the Plojesti railway-station. Over an area of some 25 acres in Baikiou, the natives utilize the inflammable vapour escaping from the earth for cooking purposes. Petroleum is usually struck at a depth of 250–550 ft. The sinking of the shafts and extraction of the oil are performed in the most primitive manner. The oil is of the denser character, its sp. gr. being 40°–48° B. It is refined at Sarate and Plojesti, affording about 40 per cent. of 1st quality lighting-oil, 20 per cent. of 2nd, 22½ per cent. of paraffin, and 17½ per cent. of residue. The raw petroleum is largely sent to Vienna, Pest, and Odessa, and some refined to Constantinople. The quality from different wells varies widely. Thus while the raw material from Sarate gives 40 per cent. of 1st quality petroleum at 42° B., the Plojesti product gives 35 per cent. of 1st quality petroleum, and 15 per cent. of benzine at 55° B. It is considered certain by Dr. Gintl that the whole Miocene formation of Roumania will be found to yield not only petroleum but ozokerit.

The Moldavian petroleum-field occupies a triangular area of over ½ million acres, bordered by the rivers Trotus and Taslin. The principal localities are Moinesti, Salante, and Comonesti, lying 25–30 *kilom.* S.-W. of the railway-station of Bacâu. Trial holes have also been sunk at Slanicu, about 7 *kilom.* S. of Okna, but hitherto without much result. The geological formation is Eocene, and bears a general resemblance to that of Galicia. In Salante and Comonesti, the wells strike oil at 150–250 ft.; in Moinesti they reach a depth of 400 ft. The whole operations are conducted in the rudest possible manner. The petroleum sells at the rate of about 1*d.* per 2½ lb. on the spot. The oil is somewhat darker-coloured than the Galician. It is almost free from paraffin, and has the low freezing-point of − 20° (− 4° F.), so that it is admirably adapted for street-lighting in winter. The sp. gr. of the raw petroleum is 1·307; of the distilled, 0·742. Distillation is but little carried on in Moldavia; there are some 10 distilleries in Salante and Moinesti, but the bulk is exported in the raw state to Roumania, Bukowina, and Galicia. The raw petroleum affords by distillation about 35½ per cent. of 1st quality lighting-oil, 30½ per cent. of 2nd quality, 17½ per cent. of tar, and 16½ per cent. of residue. The annual production is estimated by Dr. Gintl at 4000 barrels from Moinesti and Comonesti, 2000 from Salante, and 1000 from various other spots. The import of Moldavian and Roumanian petroleum into Austria by the Lemberg-Jassy railway has risen from 500 barrels in 1870 to 2350 in 1876.

Russia possesses a large territory affording petroleum. This has been officially estimated at 14,000 sq. miles, which is an obvious exaggeration. The present chief seats of the oil industry are Baku, at the S.-E. end of the Caucasian mountains; Kertch, on the Kouban river; and the neighbourhood of Zarskia Kolodza, about the centre of the S.-W. slopes. The petroleum is found in the Tertiary beds overlying Miocene, the wells having a depth of 280–350 ft. The wells and their production in 1875 were:—Kouban district, 42 wells, 230,500 *poods* (of 36 lb.); Tersk, 29 wells, 22,160 *poods*; Dagestan, 11 wells, 6200 *poods*; Apsheron peninsula (Baku), 119 wells, 6,265,728 *poods*; S. of Baku on the Caspian shores, 72 wells, 125,000 *poods*; total, 273 wells, 6,649,588 *poods*, or 105,550 tons. The extent of the Caucasian petroleum deposits is quite an unknown figure, but the indications imply an immense area, and borings have been almost everywhere successful in reaching oil. The Mogan steppe and the country around Shemaka are alluded to in a recent consular report as offering unusual inducements to prospectors, especially as about $\frac{9}{10}$ of the land is desert, utterly useless for agriculture, and purchasable at a low figure. At present everything is done in a most primitive manner; but an American firm proposes laying a pipe from Baku and the Mogan steppe to the Black Sea. Great quantities of petroleum are now allowed to run to waste. A peculiarity of the Baku petroleum is its high sp. gr., as compared with American having the same boiling-point. It gives 10 per cent. more light than American, and is more readily drawn up the wick to the flame. The high sp. gr. is availed of by manufacturers of lubricating-oil, who send into European markets an oil of 0·940 sp. gr., without any extraneous addition.

Petroleum-springs occur in Zante, one of the Ionian Islands; probably large supplies might be obtained, if proper means were adopted. In Italy, traces of petroleum, at present unprofitable, are found at Monte Zolo, and Combe di Sassatello. Egyptian petroleum has a sp. gr. of 0·953; it affords a fine lubricator, free from tarry matter, but is inferior as an illuminator. Of Indian localities, the most important is Independent Burma. Here petroleum is chiefly found near the village of Ye-nang-gy-oung, on the banks of the Irawadi. Upwards of 100 wells exist, having a common depth of 210–240 ft., occasionally increasing to 300. The wells are square shafts, 3–4 ft. across, lined with timber. The oil issues spontaneously, in inexhaustible quantities, the annual yield exceeding 11,000 tons, much of which reaches England. Petroleum-wells occur also in the British Burmese districts of Akyab, Kyouk-hpyu, and Thayet-myo, many being worked very successfully by means of British capital. Oil has been worked in the neighbourhood of the coal-fields of

S. Lakhimpur, in Assam. Two spots in the Rawal Pindi district of the Punjab afforded 2756 gal. in 1873-4. Formosa possesses large oil-grounds, which are monopolized by the Chinese Government; the oil is very slightly coloured, and of low sp. gr., and burns in lamps without being refined. Petroleum is assuming some importance as a Japanese product. It occurs principally in the provinces of Echigo, Shinano, Uyo, and Totomi. Many hundred springs are met with in Echigo; in individual spots, some 60–100 are at work. The borings vary from 2 to 600 ft. in depth. At Kanadoza, the oil flows out on the actual surface of the ground, and costs nothing but collecting. About 90 per cent. is obtained by rectification. The yield is estimated at about 750 gal. daily. The oil is of two kinds:—(*a*) clear, containing 8 per cent. of light oil, 33 per cent. of burning-oil, 48 per cent. of heavy oil, and 12 per cent. of residue; (*b*) dark, containing 9 per cent. of lamp-oil, 58½ per cent. of heavy oil, and 32½ per cent. of residue. In Shinano, the daily yield of some 40 wells is 350 gal. of oil, mostly dark-coloured, and affording only 13 per cent. of burning oil. A refinery has been erected at Niigata, capable of turning out some 4000 gal. daily, and drawing its supplies from Totomi province, a distance of 100 miles by water.

It is convenient to note that all the petroleum found in the E. United States of America is contained in a belt parallel with, and considerably to the westward of, the Alleghany mountains. The Canadian oil regions are situated in the western part of the Dominion, in the counties of Lambton, Bothwell, and Kent, Ontario province. They extend from Lake Erie to Lake Huron, and from the St. Clair river eastward for about 70 miles. The most prominent points of production are Petrolia (Lambton county), Oil Springs (Bothwell county), and Bothwell (Kent county). The petroleum is here found in a flint-bearing limestone, varying in construction, and largely composed of the marine shells and other fossils peculiar to the "corniferous" beds. The sp. gr. of the oil is 33°–43° B. (0·863–0·815 sp. gr.). The rock near Petrolia shows the following strata:—Yellow clay, 5–15 ft.; compact blue clay, 50–100 ft., resting on a thin crust of limestone, resembling stalagmite; gravel, 2–8 ft.; slate, 15 ft.; corniferous limestone, 40 ft., giving surface wells; slate, 30 ft.; limestone, 40 ft.; slate, 30 ft.; corniferous limestone 250 ft., where all the oil is found; hard blue sandstone, 4 ft.; and finally a vein of salt water, seemingly inexhaustible, as it has been penetrated for 500 ft. in several places, without yielding a barrel of oil. The entire production of the Canadian oil region is about 2500 barrels a day.

The Ohio and W. Virginia oil regions are confined to two definite belts of anticlinal geological disturbance, one extending from Newport (Ohio) northward through Washington and Morgan counties, and southward about 40 miles into W. Virginia, through Ritchie, Wood, and Wirt counties, and embracing the productive points of Horseneck, Sandhill, Volcano, White Oak, and Burning Springs; and another smaller belt lying a few miles farther west. The minimum width of the belt is about 2½ miles. The special features of this region are that oil is found in crevices at a certain fluid level, without the slightest regard to the character of the rock in which the crevices exist. Where a natural crevice is not reached by the drill, a torpedo seldom fails to open connection with one. No surface-water is found in the wells, and often no salt water. At Volcano, especially, the oil is pumped clear. It ranges in sp. gr. from 28° to 40° B. (0·889–0·829 sp. gr.), and oils of all gravities are found, indiscriminately, even in wells side by side. A section of the strata in W. Virginia and Ohio is of no value as an indication of the oil level. The production of the whole region is about 500 barrels a day.

Kentucky and Tennessee have afforded enormous quantities of oil from surface wells. A well on Crocus Creek, Cumberland county (Kentucky), at 191 ft., gave 300 barrels a day for a time; and those on Boyd's Creek, Barren county, those stretching from the Cumberland river through N.-W. Kentucky, and those in Overton county (Tennessee), indicate the probability of a large production if thoroughly developed. But the presence of sulphur in the oil, the remoteness from large consuming centres, the cost of transport, and the competition of the Pennsylvanian wells, have conspired to check extended operations here.

In Massachusetts, some wells have been sunk near Lee.

The oil basin of Shoshone (Wyoming) covers an area of about 40 acres, within which, are many points whence gas and oil are continually issuing. The oil is intensely black, and no means of decolorizing it have yet been found. On distillation, it gives 47 per cent. of kerosene flashing at 65½° (150° F.), 32 per cent. of neutral and lighter-coloured lubricating-oil, and 12 per cent. of dry coke. The sp. gr. is 20° B. (0·935); flash-test, 145½° (294° F.), and fire-test, 161° (322° F.). The Beaver basin is situated some 25 miles due east. The oil here is much lighter-coloured, varying from pale-yellow to light-mahogany. It has proved to be a good lubricant, with no unpleasant odour. It is said that millions of tons of hardened petroleum are lying about the surfaces of these basins.

The Pennsylvania oil-region proper comprises the districts of Tidioute, West Hickory, New London, Colorado, Enterprise, Titusville, Shamburg, Pithole, Petroleum Centre, Story Farm, Rouseville, Oil City, Reno, Franklin, and East Sandy, besides the Lower oil-fields, and sundry outlying districts.

In Tidioute, the first wells were sunk upon the banks and islands of the river, and yielded quantities of oil at 100–150 ft. Subsequently the sand rock was found under the hills on each side, and the best wells were bored there. The rock brought to the surface in Warren county was an open, porous conglomerate of small pebbles and a cementing matter composed of alumina and silica, friable on exposure, and capable of holding much oil. A well on the island at Tidioute drilled to 1000 ft. showed no sand below 125 ft. The best wells at Tidioute and Triumph Hill have given 400 barrels a day, and the thickness of the sand bed is not fully known, as it has only been pierced for 50–60 ft. The wells on the hill-land of the Economy tract, opposite Tidioute, merit special examination; their oil came from a region above the river level, a marked exception to all the experiences gained in the oil-region.

In the West Hickory oil area, a small quantity of heavy oil of 27° B. (0·895 sp. gr.), not exceeding 12–15 barrels per well, was obtained at a depth of 400 ft. When this ceased, a 3rd sand of 55 ft. was found at 750 ft., and very large quantities of oil have been drawn from a well of 400 barrels maximum.

The New London wells are not very large, but their production is steady and uniform. The thickness of the sand rock is 40–55 ft., at a depth of about 650 ft.

Colorado wells have, in some cases, reached 150 barrels a day, and the sand rock is found on the flat, with a thickness of about 40 ft., and at an average depth of 525 ft. The area here is probably far from being yet determined.

Enterprise has a few scattered wells, which have produced a small quantity of oil for a long time, from a sand rock 17–38 ft. thick, at a depth of about 450 ft.

The Titusville oil districts are:—1. The Watson, Guild, and Parker Flats, which gave much of the yield between 1859 and 1864. 2. The Drake Well, whose oil was found in a crevice, the well being subsequently drilled deeper, and tapping a 10-ft. sand at 150 ft., and a 55-ft. one at 370 ft., but no 3rd sand was found at 480 ft., nor in adjoining wells at 550 ft. 3. Church Run, where the sand rock does not seem to occupy quite the same geological horizon as that on the flats; the wells, while never exceeding 300 barrels, have produced largely and lastingly, the sand rock being 60–75 ft. thick, and found on the run at a depth of 480 ft. 4. In the Octave District, the wells are small but durable, and the area has not been fully defined; the sand rock is 50–70 ft. thick, at a depth of about 875 ft. 5. Miller Farm afforded some oil in 1864 from shallow wells in the 1st sand, but the quantity was inconsiderable. 6. Pleasantville. 7. National Wells have struck the 3rd sand, about 15 ft. thick, at 745 ft. on the run; the wells do not exceed 30 barrels, but the production has been considerable. 7. West Pithole wells have found a 14-ft. sand at 730 ft.

Shamburg, once a noted centre, is now nearly exhausted. The sand rock, on the run, is 60–75 ft. thick, at a depth of 775 ft. While the largest wells in this section did not reach 500 barrels, probably no locality has contained so many good wells. A marked peculiarity of the great stretch of oil-rock, of which Shamburg forms a part, is the existence of "black" and "green" oils, so called, side by side in the same territory, so that the surface line between the two classes of wells can be sharply defined. The following figures represent a minute section of a well in this district:—At 38 ft., was met a soft slate rock; 70 ft. 1st sand rock; 71 ft., water crevice; 91-112 ft., crevices; 130 ft., bottom of fine white sand rock 60 ft. thick; 132 ft., bluish-grey sand rock; 152 ft., bottom of ditto; 153 ft., slate rock, good drilling to 245 ft.; 245–256 ft., hard dark slate and sand to 278 ft.; 278 ft., hard pebble sand crust 18 in. thick; 280–289 ft., hard grey sand and slate; 289 ft., 2nd sand rock, hard pebbles, 11 ft. thick; 300 ft., bluish sand and white pebbles 5½ ft. thick; 305½ ft., grey and white shells for 29½ ft.; 338–440 ft., blue sandy rock, mixed with slate; 420–480 ft., blue and red rock alternately; 505 ft., hard blue rock crust, 15 ft. thick; 520 ft., 3rd sand, very hard, white and yellow pebbles, 10 ft. thick; 530 ft., mud vein; 545 ft., through 3rd sand 25 ft. thick, two crevices, and gas very strong; 545–575 ft., blue sand and slate to 605 ft.; 608 ft., hard crust 2 ft. thick; 610–636 ft., blue slate; 636 ft., hard white sand mixed with pebbles, a hard crust 4–5 ft. thick; 640 ft., top of 4th sand; 648–654 ft., hard pebble; 654 ft., large gas vein and show of oil; 655 ft.. bad mud vein; 668 ft., through 4th sand, 28½ ft. thick; 745 ft., hard crust of slate, 6 in. thick; 745–748 ft., hard slate; 748 ft., hard shell, yellow pebble, and good gas vein; 750 ft., slate rock; 768 ft., slate and hard shells; 776 ft., top of 5th sand; 776–8 ft., pebble rock, open and porous; 778 ft., crevice, gas vein, and good show of oil; 781 ft., rock darker; 783 ft., dark rock, gassy; 784 ft., rock porous; 792 ft., white and yellow pebble, crevice, oil, and gas; 794 ft., rock white, coarse, and porous; 806 ft., mud vein; 828–830 ft., white and yellow pebble; 830 ft., hard, close, white sand; 834 ft., slate and sand mixed; 835 ft., bottom of well.

The sand rock of Pithole, though unusually productive, had a small area in comparison with beds of more recent discovery. The Frazier and Grant wells flowed at the rate of 700 and 450 barrels a day. The sand rock on the flats of Pithole creek is 14–20 ft. thick, and at 600 ft. The chief centres in this district are:—1. Cash Up, though of small extent, was remarkable for its yield; the 1st well when drilled deep gave 1100 barrels a day. 2. Bean Farm had small wells, but proportionately lasting. 3. Bull Run and Cow Run are underlaid with a highly productive sand rock; the famous Noble well here gave 2500 barrels a day.

The Petroleum Centre oil claims overlie a fine bed of sand rock, 45 ft. thick, at 950 ft.

At Story Farm, over 180 wells, producing nearly 1 million barrels of oil, were drilled within 500 acres. The territory is now exhausted. The sand rock here is 40–45 ft. thick, at 480 ft. On the Blood, Rynd, and Tarr farms, the sand rock is 38–58 ft. thick; it has yielded enormously in former times, some of the wells giving 1000–4000 barrels a day.

Rouseville wells have struck the 3rd sand, 27–42 ft. thick, at 550 ft.; four wells on a single acre have given over 100,000 barrels of oil. The valley of Oil Creek, after producing over 110 million dollars' worth of oil from an area of less than 3 sq. miles, obtained with extraordinary waste, is rapidly declining.

At Oil City, along the creek and river-flats, fairly productive wells have been found, the 3rd sand being 20–55 ft. thick, at about 475 ft.

At Reno, the sand rock was found on the Charley Run at about 500 ft. On Sage Run, the sand rock is 18–20 ft. thick, at 900–1000 ft., and the wells have yielded up to 300 barrels each daily.

The wells of Franklin and Sugar Creek find their oil in the uppermost oil-producing sand rock on the great slope from the north-west. The rock is met with at a depth of 260 ft., beneath the flat; it is geologically higher than that of Oil City, and 50–80 ft. thick. The sp. gr. of the oil ranges from 30° to 32° B. (0·879–0·868), the most productive well giving 150 barrels a day. At Foster, the 3rd sand, 12–14 ft. thick, is struck at 610 ft.; at Scrub Grass, it is 18–20 ft. thick, at 615 ft.

East Sandy, the connecting link between the Upper and Lower oil-belts, comprises Gas City, where the sand rock was 60 ft. thick, at 850 ft.

The great Lower oil-belt has a length of some 21 miles, beginning at Triangle City (Clarion county) and apparently terminating at St. Joe (Butler county). After leaving Karns City, it splits into two well-defined beds, known as East and West. The entire width of the belt does not exceed 3 miles, but the productive area is uninterrupted, instead of being in detached spots, as in the Upper belt. The sand rock dips so rapidly in one section that the wells are there drilled to 1600 ft. An idea of the relative position of the sand rock along the belt from the upper end southward may be gained from the following data:—Turkey City, sand on flat, 20 ft., at 1150 ft.; Ocean Level of Pump Station, Turkey City, at 1179 ft.; St. Petersburgh, 26 ft., at 1241 ft.; Blanchard and Siggins' well, 26 ft., at 1063 ft.; Eddinger farm, 24 ft., at 1150 ft.; Peter King farm, 23 ft., at 1000 ft.; Casino well, 36 ft., at 1065 ft.; Murray well, 30 ft., at 1027 ft.; Bear Creek, 33 ft., at 1170 ft.; Karns City, at 1230 ft., the 3rd sand, 26 ft., at 1440 ft., and 4th sand at 1535 ft.; Modoc wells, 12–15 ft, at 1450 ft.; William Moore farm, at 1560 ft.; Armstrong Run, 3rd sand 7½ ft, at 1263 ft.; Millerstown, at 1550 ft.; James M'Cready farm, at 1530 ft.

Between the main belts of sand rock which are the great centres of production, are isolated localities, which have been more or less explored. The most prominent are:—1. Near Lowell, heavy oil at 150 ft., and gas, but no oil, at 900 ft. 2. Slippery Rock Creek, many productive wells, some up to 50 barrels, but not lasting; oil was heavy. 3. Oil Spring Reservation, surface oil. 4. Well at Limestone, at 1050 ft., gave much gas, and oil of 45° B. (0·806 sp. gr.), at first about 5 barrels a day. 5. Wells on Cow Run, about 450 ft. deep, on main belt of anticlinal in the Ohio region. 6. Wells on Duck Creek are part of same belt. 7. Utica, 7 barrels of heavy oil daily. 8. Leechburg, a gas-well, 1200 ft. deep, supplying fuel to the manufactories. 9. Tarentum, where the salt-wells, 450 ft. deep, have always found more or less petroleum within 350 ft. of the surface; some produce 8–10 barrels a day, the oil separating by the subsidence of the brine, and imparting no flavour. 10. Hosmer Run, wells found much oil at 500 ft. 11. Edinburg, a 10-barrel well, at 260 ft., heavy oil. 12. 13. Meadville, gas-well, 6-ft. sand, at 350 ft., no other sand at 1000 ft. 14. Stewart's Run, gas at 150 lb. pressure in 2nd sand, at 150 ft.; 3rd sand not found at 825 ft. 15. Cherry Run, coal-seam, 75 ft. above creek-bed. 16. Erie, about 27 gas-wells, at 450–1200 ft., average 600 ft.; one well, at 585 ft., small quantity of oil at 28° B. (0·889 sp. gr.). 17. Middlesex, small well of heavy oil. 18. Little Scrub Grass, 3rd sand at 1000 ft., and penetrated 30 ft. 19. Newell's Run, one well 5 barrels, at 525 ft.; another 10 barrels, at 236 ft. 20. Kinzua Creek, coal-bed at 600–700 ft. above the river, 4 ft. cannel, 7 ft. fire-clay, and 4 ft. bituminous coal. 21. Cherry Grove, coal-seam. 22. Bradford, a little oil and gas in a few wells in the valley. 23. Mecca, heavy oil, shallow wells, and limited yield. 24. Bully Hill, 25-ft. sand rock, one well 100 barrels. 25. Millerstown, coal at 240 ft. above the river. 26. Thorn Creek, a well that produced largely for a short time. 27. Brown and Co.'s well, 8 barrels, at 660 ft. 28. 29. Corry, gas-well, 950 ft. deep. 30. 31. 32. Wilcox, heavy oil, at 1691 ft. 33. North Rocks, conglomerate outcrop, 40–50 ft. thick. 34. Olean, 1st sand at 300 ft., 2nd at 450, 3rd at 780; last very thin, some oil, much gas. 35. West Hickory, heavy oil, small wells. 36. Smith's Ferry, oil 27°–33° B. (0·895–0·863 sp. gr.); product of wells, 25–90 barrels a week. 37. Winter's Farm, a good sand at 600 ft., 56 ft. thick, drilled 1670 ft. without finding oil, torpedoed at 600 ft., and small yield obtained. 38. Gas-well 3 miles N.-E. of East Sandy, a good sand rock of 42 ft., much gas, no oil. 39. Gas-well half-way between Gas City and Lineville. 40. Hiram Heath farm, trace of oil. 41. The Newton gas-well, 786 ft. to 3rd sand; gas production, 4 million cubic feet a day. 42. Octave District, sand rock 50 ft. thick, wells 890 ft. deep. 43. The Drake well, found oil in surface sand at 71 ft., subsequently drilled to 480 ft., but never afterwards produced much. 44. Walbridge Farm, sand rock 25 ft. thick; one well 5 barrels a day of oil at 42° B. (0·819 sp. gr.), at 750 ft. 45. Johnson Farm, 8 barrels a day, at 930 ft. 46. Cowanshannock well, no oil, much gas. 47. Fredonia, gas-well. 48. Niles, gas-wells. 49. Painesville, gas-well, 40 ft. drift clay and gravel, 648 ft. Erie shales and soapstone, 12 ft. Huron shale, very black and bituminous, with strong smell of oil, 720 ft. total depth. 50. Rock City, fine exposure of conglomerate. 51. Blyson's Run, small show of oil. 52. Little Whitely Creek, 150 ft. deep. 53. Panama, exposure of conglomerate. 54. Howeville, gas-well. 55. White Oak, oil at 80–380 ft., 26°–28° B. (0·901–0·889 sp. gr.); the same gravity oil found in one well at 300 ft., and another at 600. 56. Sugar Creek, salt spring; well sunk to 300 ft. struck oil, which mixed with the brine, and rendered it valueless. 57. Groce Farm, small well 700 ft. deep. 58. 59. 60. Sage Run, hill wells 800–1000 ft. deep, sand rock 60 ft. thick. 61. Dunkard's Creek wells. 62. Panama, at 550 ft., 6 ft. in 2nd sand; surface sand 75 ft. thick, at 344 ft.; 1st sand 30 ft., at 461 ft. 63. Jamison Farm, sand 13 ft. thick, well 240 ft. deep, small yield of oil of 48° B. (0·792 sp. gr.); well drilled to 550 ft., but no more sand found. 64. 65. Kinzua Creek, 5 or 6 wells.

While the precise location of the horizon at which the Pennsylvanian oil is found can only be determined by an examination of its entire area, a few deductions from such prominent facts as are not likely to be seriously affected by future work will be of value in conveying some idea of the nature of the search required. It is particularly desirable to obtain an accurate impression of the relative size and location upon the surface of such areas as outline the oil-bearing rocks below. It will be observed that these spots are isolated and disconnected, and, with the exception of the stretch of the great Lower oil-fields, do not comprise any continuous belt. To present this more clearly, it may be stated that, out of 3115 sq. miles of land in Pennsylvania, embracing everything which, by general acceptance, can be denominated as the oil-region, only 39½ sq. miles have actually produced oil; that is to say, all the territory that now is or has been producing could be contained in an area of 25,000 acres.

Whether the component materials or the great body of this oil exist in the sand rock where it is found, or at a depth beyond the present reach of the drill, is not a question of direct importance. What is being sought for is the location of the vent-holes by which this oil reaches within drilling distance of the surface of the earth, whether such vent-hole consists of an open sand rock or sponge as in Pennsylvania, or of an anticlinal or system of broken rocks as in W. Virginia. From the fact that coal and similar minerals are mined in continuous beds, stretching often over counties and states, it would be natural to suppose that the sand rocks of the separate oil districts are connected in the same way. The extent of the beds of the upper sand rocks, near the surface of the earth, is so much greater than that of the oil-bearing rock, that the proposition is substantially true so far as they are concerned, with the exception that they are not found at a positively uniform horizon, but overlap and underlie each other at the edges.

A well drilled anywhere in the region will find a 1st sand; and sometimes a 2nd, and invariably some "mountain sands," as they are called, are found even above these. Oil has been found in small quantities in the 1st and 2nd sand rocks, in detached spots, and from the earliest wells, but the bulk of the product has been obtained from the 3rd sand. From the means within reach at present for defining the position of this rock, there is every reason to believe that it is situated approximately throughout the region under consideration on the same geological horizon.

The productive ground in the Pennsylvania region is an area overlying, at 500–1500 ft., a bed of porous conglomerate, 3–75 ft. thick, the thickest part of the rock giving the best well, and this thickest part being generally found in the centre of the area, the rock tapering off at the edges.

When a well is drilled in an untried locality, and the 3rd sand rock is found of any thickness, whether with much or little oil, this well is followed by others situated in different directions from it, until the thickest part of the sand rock is discovered, and a good well is the result; and it is not long before the edge, where the rock thins out, can be mapped on the surface of the ground above it. There is, therefore, within reach of the drill, no continuous bed of oil-bearing sand rock, but a series of scattered disc-shaped deposits. These separate and detached beds of 3rd sand rock are lens-shaped, being thin at the edges, as before stated.

The use of the term "oil-belt," has led to some misconception; lines which were run across the surface of the country for many miles, in courses varying from N. 14° E. to N. 22° E., have been found to intersect the surface directly over these producing beds of 3rd sand, but in separate places, and widely apart. The value of this discovery is doubtless confined to the extent of the conformity of these lines with the general course of the current which transported the material to form the deposit.

It would seem that all the oil rocks of the region, even if they be disconnected and scattered through the strata at irregular distances, lie at about the same general geological horizon.

The lowest sand rock as yet reported by any oil driller is in Jonathan Watson's deep well, which was drilled on the flat, in the City of Titusville, at a point 1195 ft. above sea-level, and in which a sand 20 ft. thick and containing some green oil, was said to have been passed through at a depth of 1976 ft. This sand was described as a white pebble conglomerate, similar in every respect to the ordinary 3rd sand. The next is the reported 3rd sand of Watson's well at a depth of 1507 ft. from the surface. The lowest 3rd sand of the oil-region proper is found at Tidioute, at a depth of 140 ft. below the first bench on the river, but not at a corresponding depth under the hills on either side. The sand rock there, if it be the same, is considerably higher; but when penetrated, in the hopes of finding the river-sand, only "knocked the bottom out of the well." No small amount of oil has been produced from a 1st sand at Tidioute, found on the river at a depth of less than 100 ft. On the river-bank of the Economy tract, a well struck in a crevice at 99½ ft., in 1861, produced oil steadily for 8 years; and 4 other producing wells in the vicinity were not over 150 ft. in depth. From Enterprise and Titusville to Oil City, the 3rd sand, which is found at an average depth of 450 ft., follows nearly the fall of the water-shed, being found at Oil City at a depth of 475 ft., and along Oil Creek almost uniformly between these points. At Petroleum Centre, there appears to be a similar deviation; also at Church Run, near Titusville. Surface oil has, likewise, been found in the 1st and 2nd sand rocks on Oil Creek. The Drake well found the sand at 71 ft., and produced for some time 25 barrels a day. Some wells at Miller farm also found oil for a short time at 225 ft., in what was probably a split 1st sand.

The fall of the sand rock progresses uniformly through intervening sections to Scrub Grass, on the Allegheny river. Here, it is found, that while the oil-bearing sands on Beaver creek are also apparently uniform in general horizon with the dip or fall north of them, yet from this point southward along the belt, the dip is so much more rapid, that without the fortunate coincidence of the lowest line of water-shed being with the direction of the development, the wells would, before this, have attained a very undesirable depth.

The explanation of the phenomenon of a 4th sand, as it is called, which is found on the cross-belt from Armstrong Run to Greece City, and its precise geological location, requires the closest research. Whether it is a separate sand rock deposited by a cross-current on a lower horizon, or whether it is only a divided 3rd sand, is yet a matter of question. The formation immediately above it is almost identical with that above the 3rd sand of the grand belt. A thin hard shell which caps it is found in a similar position at Millerstown. The levels taken so far seem to indicate that it occupies the same position as the 3rd sand. The 4th sand at Karns City is 25 ft. thick, of a red and yellow colour, and lies about 70 ft. below that known as the 3rd sand.

America is at this moment supplying almost all the world's needs of petroleum. But it is producing in reckless haste, at a positive loss to the community at large, and regardless of all consequences save the present bountiful supply. Considering the short life of the best territory that has been found, and the relative smallness of the productive area in proportion to the entire region, it is a serious question, even in the face of the enormous output of to-day, whether the United States will continue to supply petroleum to the next generation. The total exports of petroleum from the United States in 1879 were 25,874,000 gal. crude, and 349,128,000 gal. refined.

The exports of refined from New York (in gallons) in the years 1878 and 1879 respectively were thus distributed:—Great Britain, 29,918,226 and 47,186,757; Germany, 48,374,179 and 64,130,182; Norway and Sweden, 3,928,374 and 5,480,157; Russia, 1,811,288 and 2,670,900; Denmark, 5,886,528 and 5,809,642; Belgium, 11,251,387 and 16,156,629; Holland, 8,623,656 and 11,010,971; Spain, 6,783,785 and 7,693,336; Portugal, 1,356,800 and 1,973,427; Gibraltar and Malta, 2,480,342 and 1,857,396; Italy, 3,018,291 and 2,449,128; Austria, 5,807,423 and 9,989,863; Greece, 1,594,220 and 1,513,650; Turkey in Europe, 4,537,276 and 3,605,440; Turkey in Asia, 2,922,550 and 1,404,660; India, nil and 8,502,080; China, Japan, &c., 24,615,545 and 18,803,770; E. Indies, 8,861,345 and 23,688,516; Egypt, 1,555,666 and 3,749,843; Canary Islands, 109,033 and 82,976; other African ports, 1,719,518 and 2,359,170; Australia, 2,476,982 and 2,277,346; New Zealand, 811,993 and 352,260; Sandwich Islands, 32,000 and 45,850; Brazil, 3,497,578 and 4,220,973; Argentine Republic, 1,632,985 and 1,742,857; Chili and Peru, 1,062,115 and 936,872; Colombia (New Granada), 2640 and 38,060; Venezuela, 421,182 and 527,152; other S. American ports, 33,500 and 26,100; Central America, 164,718 and 216,008; Mexico, 546,921 and 850,583; British N. America, 312,329 and 237,645; Cuba, 2,144,292 and 735,942; British W. Indies and Guiana, 1,227,602 and 1,388,057; other W. Indies, 804,058 and 987,118; totals, 190,406,227 and 254,701,316 gal.

In addition, the exports of crude oil in the same years were:—France, 12,900,049 and 17,931,418; Antwerp, 170,320 and 140,506; Bremen, 1,102,060 and 2,133,847; Norway and Sweden, 46,324 and nil; Spain, 113,000 and 1,873,167; Cuba, 344,786 and 1,680,800; totals, 14,576,539 and 23,759,738 gal. The naphtha exports were:—Great Britain, 4,871,170 and 7,674,523; France, 2,732,418 and 4,864,165; Germany, 712,531 and 1,110,776; other Europe, 1,314,756 and 1,800,010;

various ports, 109,926 and 81,567; totals, 9,740,791 and 15,531,041 gal. And the shipments of residue to all ports were 3,006,694 and 4,670,854 gal.

Philadelphia ranks second in importance for the shipment of petroleum. The exports thence of refined in 1879 (in gallons) were:—Austria, 6,552,054; Belgium, 14,241,302; Brazil, 87,501; Denmark, 1,491,304; French W. Indies, 2000; Germany, 27,623,838; England, 1,874,056; Gibraltar, 1,561,591; British W. Indies, 12,456; other British possessions, 116,000; Italy, 17,143,725; Japan, 1,855,200; Netherlands, 8,079,697; Portugal, 688,771; Spain, 122,544; Cuba, 27,557; Porto Rico, 5000; Norway, 267,332; Sweden, 461,633; Turkey in Europe, 100,000; Egypt, 56,530; Colombia (New Granada), 52; Venezuela, 18; total, 82,370,211 gal. The exports of crude were:—France, 2,666,665; Germany, 368,600; Spain, 179,481; Cuba, 1500; Sweden, 25,257; total, 3,241,503 gal. And of naphtha and benzine:—France, 1,617,451; Germany, 243,853; England, 773,866; Sweden, 114,857; total, 2,750,027 gal.

The total shipments from Baltimore, the only other centre of importance, were:—44,874,861 gal. in 1877, 37,712,900 in 1878, 23,322,482 in 1879, and only 14,780,980 in 1880.

Of the W. Indian Islands, Trinidad, Cuba, and Barbadoes are known to possess petroleum-deposits, but they have been turned to little account; Barbadoes exported 2424*l.* worth in 1877, and 1437*l.* in 1878. Venezuela produces large quantities of rich bitumen fit for distilling, and minor contributions of petroleum; a remarkable outburst of petroleum occurs between the Rio Tara and Zulia, one hole out of many giving 240 gal. an hour. In the neighbouring republic of Colombia (New Granada), petroleum is met with between Escuque and Bettijoque. Peru has afforded petroleum from time immemorial. The Argentine Republic has recently commenced to develop its resources in petroleum at Laguna de Labrea, in Jujuy, where numerous springs exist. In S. Australia, a remarkable petroleum district has just been opened out on the banks of the Coorong, about 6 miles north of Salt Creek. A number of Australian capitalists have begun to work the petroleum-springs in the Poverty Bay district of Auckland, New Zealand, and other springs are known of on the same coast.

There are three principal localities, each producing a distinct kind of oil:—(1) The Sugar Loaves, in Taranaki province; (2) Poverty Bay, on the E. coast of the province of Auckland; (3) Mauntahi, Waiapu, East Cape. The oil from the first has a very high sp. gr., 0·960–0·964 at 15½° (60° F.). It has thus too much carbon in its composition for its commercial success as an illuminating-oil, but is capable of producing a valuable lubricating-oil. It resembles oil occurring in Santa Barbara county, California. The second kind, from Waiapu, Poverty Bay, is a true paraffin-oil, resembling the Canadian oil. By three successive distillations, and treatment with acids and alkalies, about 65 per cent. of a good illuminating-oil is obtainable, with a sp. gr. of 0·843. The third produces a pale-brown oil, nearly or quite transparent, of sp. gr. 0·829 at 15½° (60° F.), burns well, contains only traces of paraffin, and produces 84 per cent. of an illuminating-oil, fit for kerosene-lamps, by a single distillation; by two more distillations, 66 per cent. of the crude oil has a sp. gr. of 0·811, which is that of common kerosene. At Sugar Loaf Point, Taranaki, the petroleum oozes from cracks in trachyte breccia. Wells have been bored to the depth of many hundred feet, but no steady supply of oil has been obtained. Crude oil has a sp. gr. of 0·962 at 15½° (60° F.), and yields, by fractional distillation, oils having the following gravities:—2 per cent. of oil of sp. gr. 0·874, 10 per cent. at 0·893, 8 per cent. at 0·917, 60 per cent. at 0·941; or a total of 80 per cent. distilled off, with 6·1 per cent. solid bitumen, 12·4 per cent. fixed carbon, and 1·5 per cent. ash.

The following is an analysis of the petroleum found at Waipawa River, Poverty Bay, Auckland: —2 per cent. of oil of sp. gr. 0·809 (colourless), 16·0 per cent. at 0·826 (nearly colourless), 16·0 per cent. at 0·836 (pale-yellow), 19·0 per cent. at 0·850 (dark-yellow), 11·0 per cent. at 0·850 (brown, [solid at 4½° (40° F.)]), 8·0 per cent. at 0·864, 21·25 per cent. paraffin-oil; or a total of 93·75 per cent. distilled off, and 6·25 per cent. of residue in the retort (pitch).

At Waiapu, East Coast, Auckland province, the crude oil has a sp. gr. of 0·872 at 14½° (58° F.); boiling-point, 143° (290° F.); flashing-point, 110° (230° F.); a sample with a sp. gr. of 0·829 gives 40·0 per cent. of oil of sp. gr. 0·800 (colourless), 33·0 per cent. at 0·826 (pale-coloured), 12·5 per cent. at 0·840, 6·25 per cent. at 0·860, and 4·25 per cent. at 0·870; or a total of 96·00 per cent. distilled off, and 4·00 per cent. of residue in the retort. Another analyis yielded 12·20 per cent. of sp. gr. 0·820 (fine lamp-oil), 37·75 per cent. at 0·853 (inferior lamp-oil), 26·69 per cent. of lubricating-oil, 16·00 per cent. of paraffin; or a total of 90·64 per cent. distilled off, and 9·36 per cent. bituminous residue.

Boring and Pumping Oil-wells.—Ready-formed outlets for petroleum are rarely found, and usually the earth has to be bored for a considerable depth to reach the productive level, and the oil then generally requires to be pumped out. This branch of the subject divides itself into four principal heads—the "rig," the well, drilling-tools, and pumps.

The Rig.—The rig is composed of a derrick, band-wheel, bull-wheel, sand-pump reel, sampson-post, walking-beam, and engine-house. The present derrick is built "balloon-frame," 16–20 ft. sq.

at the base, and 60–72 ft. high, resting on hewn oak sills 12 by 18 in., framed and pinned at the corners; the four corner-posts are of pine plank 10 by 2 in., spiked together at right angles, and connected with cross-ties and diagonal braces of 8 by 1½ in.; the top holds the usual cast-iron derrick-pulley, and a ladder to reach it is constructed upon one side.

The bull-wheel now in use has four main arms of oak, 8 by 2½ in., passing clear through the shaft, and locked and keyed; the false arms between, 6 by 2 in., wedge upon each at the shaft, and are firmly held by the three thicknesses of pine boards forming the outer rim.

The total length of oak shaft is 10½–12 ft., its diameter 13 in., its length between wheels 6–7 ft., diameter of wheels 6½–7 ft., and bearing-pin on ends 2½ by 4 in.

The brake is a simple iron strap applied under the bull-wheel; a wooden pawl is made to fall from above, against the arms, as a permanent stop, when desired.

The band-wheel is built of inch pine lumber, surfaced to a uniform thickness, the present diameter being about 7 ft.; the rope-pulley on one side is 5 ft., and the face of the wheel 9 in. The grooves of the rope-pulleys on both band- and bull-wheels are made of hard wood, and, to ensure a perfect outer circle, the edges are turned off after the wheels are firmly mounted on the shaft and revolved on temporary bearings.

The sand-pump reel has always been the most awkward part of a well-rig; acting as a friction-pulley against the band-wheel with the bevelled face necessitated by the different angle of the shaft, its tendency was to self-destruction, even when most carefully and securely fitted up. A solid wheel of hard wood with wooden keys is sometimes used; also a piece of casing as a shaft, with a cast-iron pulley keyed upon it. The best reel is an oak shaft, about 8 ft. in length, 8 in. in diameter, with arms of the wheel passing through the shaft and enclosed with an iron rim.

The sampson-post and walking-beam have gradually increased in size, until the one is a post 20 in. sq., and the other 24–26 ft. in length, with a section at the centre of 30 by 18 in. The great weight of the walking-beam has, perhaps, some of the effect of a fly-wheel, where a fly-wheel nevertheless is not found to be a practical success. The utmost care is needed in making the foundation of the sampson-post and band-wheel frame perfectly solid and substantial; two long hewn sills for the latter, not less than 12 by 20 in. in section, pass clear under the derrick-sills; the jack-posts, cap, and braces of the band-wheel frame, being of pine 10 by 12 in., the cap bolted through to the sill.

The Well.—Col. Drake's invention of the driving-pipe affords the best means of passing through soft overlying earth to the rock. The pipe used at present is 8 in. in diameter, of 1-in. cast-iron, driven down into the earth in sections of 8 ft. in length, connected with wrought-iron bands, heated and shrunk on. Putting down a thin iron pipe of 6 in. diameter below the lowest fresh-water vein, and retaining the surface-water by a water-packer between the outside of the pipe and the wall of the well, enables the driller to proceed without annoyance from this source, and, when the well is completed, to take his tubing out of the well at pleasure, still keeping the water permanently from the oil-bearing rock. In fact, the entire operation of drilling and pumping is carried on through the casing, and not until a well is finally abandoned is the casing withdrawn.

The modern water-packer is a great improvement on the bag of flaxseed formerly used; the weight of the column of water presses the leather against the sides of the well, forming an effectual stopper. By means of a left-handed thread, it can be loosened in a few minutes, and drawn out of the well without difficulty.

Drilling-Tools.—A set of drilling-tools, as used to-day, weighs 1800–2600 lb., and costs about 70*l.* It consists of a temper-screw, rope-socket, auger-stem, sinker-bar and substitute, the jars, two bitts, a round reamer, a flat reamer, and two wrenches. The temper-screw varies little from that in former use, except in size, the present length being about 5 ft. The auger-stem, sinker-bar, and substitute are respectively 24, 14, and 5 ft. in length, the last being used in starting a well. They are made in the body, of common round iron (2½–3 in.), with boxes and pins of Norway iron. Pins are 2¾ in. in length, 2⅜ in. in diameter, 8 threads to the in., and with the least possible taper, to prevent being loosened by the constant jar, which also has a tendency to crystallize the iron in the pins and boxes, making it necessary to renew them at intervals.

The jars are made entirely of Norway iron 2 in. sq., with the exception of the inner faces and ends of the slotted openings, which are lined with steel, the whole being heated red-hot and carefully annealed, to effect a thorough union of the metals. The stroke of the jars has been reduced to 12 in. and their total length is about 6 ft.

The bitts are made of Norway iron, with 40 lb. of steel on the point, which is drawn to a width of 5½ in., more or less, according to the size of the well. The flat and round reamers are made also of Norway iron, with more steel on the point.

There are also various extra tools for different purposes.

The hollow reamer is for straightening a crooked hole. A spud or spoon for enlarging the well around a stuck tool, is simply half a hollow reamer; a slip-socket is to drop over the head of a tool that is fast, with dogs or teeth to fall out and catch under the collar; a horn-socket, or tapering iron tube, is to drive and wedge upon the head of any fastened iron. All these, with many others, often especially devised and constructed for the purpose, are required at various times in sinking a well. The cable used is 6-in. untarred manilla rope.

The sand pump has two improvements : (1), the valve with a drop-stem to open it on reaching the bottom of the well ; and (2) the piston which keeps its place at the bottom of the pump while being lowered, but when drawn up, fills the pump by its suction with the loose debris and water.

Pumps.—The main improvements under this head are included in the two items of sucker-rods and valves. The old style of sucker-rods with fish-tail ends has passed out of use, the rivets constantly becoming loose and dropping into the working barrel having given great annoyance. To remedy this, the joint is made without any rivets ; the wood is driven into a metallic socket and widened at the end with a wedge, an intermediate piece of small tubing making a screw connection between the two sockets.

The valves in use are a plain standing valve at the bottom of the working barrel, and a 3- or 4-cup valve, or a water-packer of some kind ; special valves are made for gas when it predominates largely in a well, and to meet the several conditions which occur. The body of the sucker-rod is made of the best upland ash, 1½ in. in diameter, and 24–28 ft. long.

Transportation.—The first producing wells being found upon the flat land of Oil creek and the Alleghany river, the removal of the product was not a matter of great difficulty, as flat-boats conveyed the oil down stream to the nearest railroad. The railroads gradually extended their branches along the valleys of the region, but the oil produced from inlying valleys or remote spots had to be conveyed in barrels by teams, often a distance of 10–12 miles, and at great cost.

To remedy this, recourse was had to conveyance in pipes, and a 4-in. cast-iron pipe with leaded joints was laid in 1861 from Titusville, four miles down the creek. Owing to imperfect construction, it was a failure, and all projects of the kind were abandoned until 1865, when Samuel Vansyckle conceived the extension of the tubing of the well, as it were, to the station desired, and laid the first line of 2-in. tubing six miles in length, from Pit-hole to Miller farm. The success of this line caused the matter to be taken up by others, and the length of lines in the Pennsylvanian oil-region now reaches an aggregate of nearly 2000 miles, and 15 separate companies are engaged in the transportation of oil by pipe from the wells to the railroad.

The tubing in common use for well and shipping purposes is made of wrought-iron plates, of No. 6 or 7 wire gauge, heated in a furnace, and closed around a cold iron core ; the joint in the lap-weld tubing is formed by passing it, while hot and soft, through a series of rollers, which first turn up the edges, and then press or weld them down upon each other. In butt-weld tubing, the edges are simply heated to a white heat, and then rolled together. Tubing for oil purposes must stand a test of 1200 lb. a sq. in. of internal pressure, a strength which is attained only by lap-weld.

In a pump for a pipe-line, the essential elements are a long stroke, a small oil-cylinder, and a large steam-cylinder. The air-chamber also must be proportioned to the work of the line, for the capacity of the pump is substantially the capacity of the line. There should be no obstruction in the line, especially at the point of delivery ; a simple bend of the pipe at the receiving-tank will add many lb. pressure to the pump. All stop-cocks and connections should be free-way stop-cocks.

The experience acquired in the construction and management of pipe-lines in the oil region has shown the comparative economic value of this method of transportation. The adoption of this method is based upon the quantity of the fluid to be carried being ample and correspondingly cheap. To arrive at an estimate of the relative values of railroad and pipe-line transportation, it is necessary, in the computation of the working capacity and required force of a pipe-line, to note that 75–80 per cent. of the pumping force required by a pipe-line is necessary to overcome the friction dependent on the velocity of flow. Also, that in building a line, if the pipe were made very heavy, one pump would force it a long distance, and save the cost of labour and fuel attendant on intermediate stations ; but that, if there were a great many intermediate stations, the pipe could be made very light, and the expense of construction be greatly reduced, the cost of fuel and labour being proportionately increased. The mean length of line which can be operated to advantage by one pump, with the lines at present in use, is about 15 miles ; with care in the construction of the line, it could be extended to 20 miles.

In the construction of ordinary lines, which are of equal thickness for their entire length, there is just twice the amount of iron used that is actually required. The area of internal section of a 3-in. pipe is 7·06858344 sq. in. ; contents of line (20 miles), 105,600 ft., 38,776 gal., or 901 barrels ; to deliver 3600 barrels a day would require a velocity of flow of 5 ft. a second. Weisbach's formula to ascertain the head required to overcome friction, is as follows :—

$$\left(\cdot 0144 + \frac{\cdot 01746}{\sqrt{v}}\right) \times \frac{l}{d} \times \frac{v^2}{5 \cdot 4} = h'$$

h' = head required in feet.
v = velocity in feet per second.
l = length of the line in feet.
d = diameter of the pipe in inches.

This formula applied would be

$$\left(\cdot 0144 + \frac{\cdot 01746}{\sqrt{5}}\right) \times \frac{105600}{3} \times \frac{25}{5\cdot 4} = 2473\cdot 9$$

In practice, this is found to be, for these long pipes, about 25 per cent. in excess, where the route is carefully selected, and the line is properly laid. As these lines follow vertically the contour of the ground in a hilly country, this is somewhat remarkable, especially when it is considered that no account is taken of any increased friction for the rise of the line in many places above the hydraulic mean gradient, from the highest point to be overcome to the point of delivery.

If the line be enlarged at every five miles,

5 miles of 3-in. pipe will require a friction-head of	618·5 ft.
5 „ 3¼ „ „ „	570·9 „
5 „ 3½ „ „ „	530·0 „
5 „ 4 „ „ „	464·0 „
Total	2183·4 ft.

Being a saving in head of nearly 300 ft.

An equivalent to this gain may be obtained by a reduction of the diameter of the pipe at the pump, or by an increased velocity, thus:—

	Velocity.	Friction-Head.	Contents of Section.
		ft.	bbls.
5 miles 2¾-in.	5 ft. 9 in. a sec.	674·9	187
5 „ 3 „	5 „ 0 „ „	618·5	225·2
5 „ 3¼ „	4 „ 2 „ „	570·9	264·5
5 „ 3½ „	3 „ 6 „ „	530·0	306·8
		2394·3	983·5

Being still less than the friction-head required for a continuous 3-in. pipe.

It will also be found that the reduced line contains 983·5 barrels instead of 901; and since the element of friction represents the greatest resistance to be overcome, the enlargement will cause a constant reduction of velocity, and therefore of friction.

In 20 miles of straight pipe there will probably be elevations to overcome. Assuming 400 ft. as an extreme, and adding it to the head required, the total head will be:—

	Head Required.	Pressure on sq. in.
	ft.	lb.
At the pump, 2¾-in. pipe	2794·3	1212
Beginning of second 5 miles, 3-in. pipe	2119·3	919
„ third 5 „ 3¼ „	1500·9	651
„ fourth 5 „ 3½ „	930·0	403

The head of 400 ft. is carried through all the sections, in the absence of given levels of any actual line; otherwise the heads and pressures for the last two or three sections would be very much reduced.

Weisbach's formula was based upon the results obtained with water; by multiplying the pressures given by the difference in sp. gr. of water and the oil of commerce, 0·7972, we get:—

	Pressure on sq. in.	Thickness of Metal in Pipe.	Weight of Pipe per ft.
	lb.	in.	lb.
1st section	969	0·167	6·709
2nd „	735	0·138	5·537
3rd „	521	0·093	3·799
4th „	322	0·071	2·910

The first section will contain 177,117 lb. of iron; 2nd, 146,176 lb.; 3rd, 100,320 lb.; 4th, 76,824 lb.; total, 500,437 lb.

The weight of the line, if made of the ordinary 2-in. tubing in the usual manner, would be 387,235 lb.; and its capacity for delivery would be but 1000 barrels a day, against 3600 in the line described. The work of the line would equal 366,291,200 gal. raised 1 ft. high in 24 hours, requiring for its exertion a horse-power of 77 for water, and 62 for oil.

From these data, the following estimate of the cost of a 20-mile pipe may be made:—

500,437 lb. iron @ 9 cents, delivered on ground	$45,039 33
10,000 lb. fittings @ 20 cents	2,000 00
Laying pipe in trench 2 ft. deep, 6400 rods @ 60 cents	3,840 00
70 h.-p. boiler, pump and station, complete	10,000 00
Telegraph line	2,000 00
1000-barrel tank, iron	1,000 00
Sundries	1,120 66
(£13,000)	$65,000 00

To move this 3600 barrels of oil a day would require the direct services of four men; two engineers relieve each other at the pump every 12 hours, one man receives the oil from the wells and keeps the gauges, and one man receives and ships the oil at the railway-station.

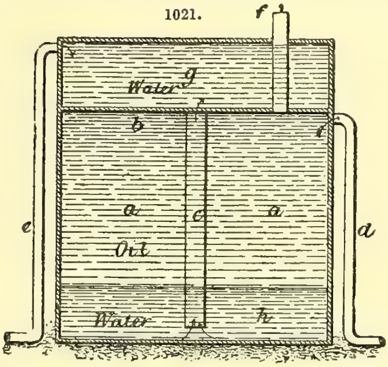
The cost of an engine and train of 36 tank-cars, which would be required to carry 3600 barrels of oil, would exceed the cost of the entire pipe-line, exclusive of any estimate of the cost of the roadway, which is about ten times the cost per mile.

With an ample supply of the fluid, and the required number of 20-mile sections, the estimate made would cover any distance required.

Storing.—The storage of petroleum in bulk is generally effected in huge tanks made of boiler-plate, varying in capacity from 8000 to 25,000 barrels (of 42 gal.). The top is more usually of wood than of iron. Wooden tops are often recessed so as to hold a body of water, or are covered with earth. Tops are always provided with man-holes, giving entrance to the tank for cleaning and repairs. The supply-pipe, which may conduct the oil from wells many miles distant, feeds at the top of the tank, near the man-hole; and draw-off taps are fixed at about 1 in. above the bottom. A distance of at least 200 ft. should separate tanks, in case of fire.

This system has proved quite ineffectual in preventing the ignition of stored petroleum by lightning, and in confining the fire when once it has broken out. Relying upon the fact that petroleum will not ignite unless it is vaporized, E. A. L. Roberts, of Titusville, Pennsylvania, has devised a lightning-proof tank, as shown in Fig. 1021: *a*, oil-space; *b*, diaphragm; *c*, balance-pipe; *d*, filling and emptying oil-pipe; *e*, inlet and overflow water-pipe; *f*, vent-pipe; *g*, water layer above the oil; *h*, water layer beneath the oil. The tank is first filled with water by the pipe *d*, entering the tank immediately under the diaphragm; the admission of water is continued until it has passed up the balance-pipe *c*, and filled the space *g*, driving out the air by the vent *f*. Petroleum is then forced through *d*, displacing the water, which passes up *c* into *g*, the surplus escaping by the outlet *e*. Sufficient water is left to form a layer of about 6 in. on the bottom, and at least as great a depth remains above the diaphragm. When the vent *f* is closed, no air can mingle with the petroleum, and no evaporation can take place. In order to draw oil out, water is forced in by *e*.

1021.



A plan projected by Donny embraces the storage in both bulk and barrels, so as to be free from danger of ignition by any ordinary occurrence, such as lightning, and to confine the fire and the burning material in case of a conflagration. The cisterns are constructed of concrete, with vaulted roofs, preferably below the surface of the ground; if above, the walls must be kept moist, to prevent leakage. For storage in bulk, a number of tanks are formed of concrete, communicating by siphon-pipes, into and out of which the oil is passed by pumps. The barrels are stored in long concrete vaults, closed by a double system of airtight doors, made of light sheet iron, and so arranged that if one is blown out, the second will fall into its place. Supposing the doors to act, in case of an explosion, the first door will be blown away, when the second resumes its place, shutting off air, and smothering the fire; should the doors not act, the burning oil will flow along a passage specially provided for it into an immense cistern, and meantime the air-supply can be cut off by banking up earth in the doorways.

With regard to the material for the construction of petroleum receptacles, Dr. Stevenson Macadam states that lead will spoil lamp-oil in a week, or less if bright; iron does not detract from the illuminating qualities, but deepens the colour, and causes a rusty deposit; zinc, solder, and galvanized iron are all deleterious. Metals which do not seriously damage the oil, but which still cause its deterioration by contact prolonged for months, are tin, copper, and tinned copper, common solder containing lead being excluded from use in their manufacture. Stoneware, slate, and enamelled iron are recommended as superior to all metals.

A very curious circumstance, which may be turned to some practical account, is that the addition of a little powdered soapwort (*Saponaria officinalis*), digested in water, causes petroleum to form a solid mucilage, and that the subsequent application of a little phenol (carbolic acid) causes it to resume perfect limpidity.

Separation of the Constituents, and their Uses.—Crude petroleum is usually a dark greenish-brown liquid, of somewhat offensive odour, having a density varying from 40° to 48° B. (0·820–0·782 sp. gr.), and composed of not less than 30 distinct hydrocarbons capable of separation by heat. To prepare the oil for commerce, it is freed from both the heaviest and the lightest members. The operations are directed to the separation of the following matters:—(1) The light oils, which are highly volatile and inflammable; (2) the heavy oils, which do not illuminate well, but are good lubricators; (3) tarry matters; (4) colouring matters; (5) malodorous matters. This involves 3 or 4 distinct processes:—(1) Fractional distillation; (2) agitation with sulphuric acid; (3) agitation with hydrates of soda and ammonia; (4) washing with water; (5) occasionally a second distillation after the acid and alkali treatment.

The distillation is effected in an iron still, provided with a condenser-coil. (Several forms of still used in fractionizing coal-tar will be found described on pp. 641–4, and much information bearing upon the subject is scattered throughout the article on Coal-tar Products, pp. 641–684; see also Paraffin.) The matters first issuing from the still are very volatile gases, which escape condensation at ordinary temperatures, but which, by cooling and compressing, may be converted into the volatile liquids rhigolene and cymogene. As the distillation proceeds, the issuing matters take a liquid form at ordinary temperatures, and increase in density, from 95° B. (0·629 sp. gr.) downwards. These oils may be separated according to their densities as they come over; but it is more usual first to collect in one receiver all the oils that pass over between 95° and 65° B. (0·629–0·723 sp. gr.), constituting (*a*) "crude naphtha," and to effect the breaking-up of this crude naphtha by a subsequent operation. When the distillate shows a density of 65°–59° B. (0·723–0·748 sp. gr.), it is run into the (*b*) "kerosene" tank, until the density reaches about 38° B. (0·838 sp. gr.), or the colour deepens to yellow. The next portion is then collected as (*c*) paraffin-oil, until nothing but pitch or coke remains in the still, the density of the last products being about 25° B. (0·906 sp. gr.). The distillate (*a*) "crude naphtha," by redistillation, is broken up into "gasolene," or "light naphtha," ordinary "naphtha," and "benzine." The "kerosene" or lamp-oil, forms the bulk of the product. This is agitated with about 2 per cent. by volume of sulphuric acid, to remove the disagreeable odour and a portion of the colour. Thus partially cleansed, it is washed with water, then with alkali (hydrate of soda or ammonia) to correct the remaining traces of acid, then with water to remove the taint of alkali. Sometimes it is redistilled at a higher temperature than before to remove the small percentage of naphtha or benzine still present. Finally it is exposed in open tanks, under glass, to the sun, for 24 hours or so, to complete the bleaching and sweetening. The extra price at which kerosene is sold tempts many distillers to neglect the separation as just detailed, and to mix as much benzine and naphtha as possible with the kerosene. The tendency of this is to reduce the flashing-point (see p. 1479) in a remarkable degree, and to render the oil totally unsafe for illuminating purposes; an oil flashing at 113° F. was reduced to 103° F. by the addition of 1 per cent. of naphtha, and to 83° F. by the addition of 5 per cent., while with 20 per cent., the mixture actually burned at 50° F. The annexed table shows at a glance the densities, proportions, uses, and relative market values of the several products of the fractional distillation of crude petroleum:—

Product.	Density.	Percentage.	Application.	Price per gal.
Cymogene	105°–115° B. (0·603–0·578 sp. gr.)	..	Artificial freezing	6*s.*
Rhigolene	95°–105° B. (0·629–0·603 sp. gr.)	..	Anæsthetic	4*s.*
Gasolene	80°–95° B. (0·673–0·629 sp. gr.)	1½	Air-gas lamps	9–18*d.*
Naphtha	65°–80° B. (0·723–0·673 sp. gr.)	10	An adulterant of kerosene	2–4*d.*
Benzine	60°–65° B. (0·744–0·723 sp. gr.)	4	Paints and varnishes ..	6–8*d.*
Kerosene	38°–60° B. (0·838–0·744 sp. gr.)	55	Lamp-oil	10–12*d.*
Paraffin-oil ..	25°–38° B. (0·906–0·838 sp. gr.)	19½	Separated into paraffin and a lubricating-oil ..	7–9*d.*

The substance called "vaseline" is the residue from the distillation of petroleum, purified by an elaborate process. It is a pale-yellow, translucent, slightly fluorescent, semi-solid, of sp. gr. 0·840 at 54° (129° F.), insoluble in water, slightly soluble in alcohol, freely in ether, and miscible in all proportions with fixed and volatile oils. Being unchangeable, it has been proposed as a basis for ointments, perfumes, and other compounds where fat is usually employed.

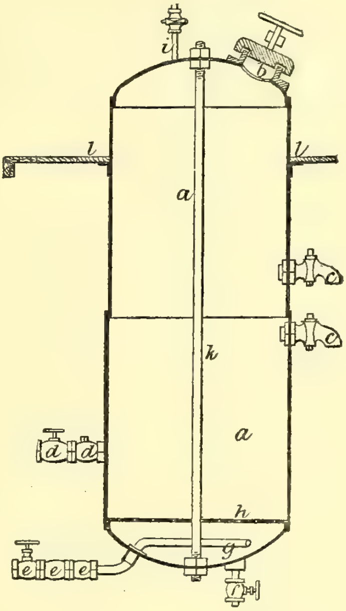
GENERAL CONSIDERATIONS.

Improved Modes of Extraction. *Animal Fats.*—One of the most important operations under this head is the manufacture of tallow and lard from animal fats. The process is usually termed "rendering," as applied to the fats themselves. These fatty matters are contained in animal tissue, into whose composition water largely enters. The simplest method of separating them from each other is by heating the fat in an open pan over a fire, at a temperature considerably above the boiling-point of water, 100° (212° F.), constantly stirring the mass, whereupon the animal tissue dries and cracks, allowing the pure fat to run out, and become separable by mere straining. This process, however, requires careful watching, as the tallow is apt to be discoloured by overheating, and, unless the fat be very new, is certain to evolve noxious odours.

The methods employed on a large scale may be divided into two, according as it is desired to save the animal tissue in a solid form, or not. If it be so desired, a very suitable apparatus is that used by Dole, of Bristol, and made by Miles, engineer, Bristol, shown in Fig. 1022. The apparatus consists of a strong iron cylinder *a*, provided above with a charging-hole *b*, closed by a sliding cover; a man-hole near the bottom, for the discharge of solid refuse; two taps *c* for drawing off pure fat; water feed-valves *d*; steam feed-valves *e*; and water draw-off valve *f*. Steam at a pressure of 60–80 lb. is introduced at *e*, and circulates in the coil *g* below the perforated false bottom *h*, *d* supplying water when necessary. The vent-tap *i* regulates the pressure, and permits the blowing off of steam. The apparatus being charged, steam is introduced for 6–8 hours. With a heavy charge, the fat can be drawn off by the upper of taps *c*, being floated to that level if necessary by letting in water. With a light charge, it is considered better to draw off all liquids together by the lower tap *c*, and skim off the fat when cold. The apparatus is strengthened by a stay-bolt *k*, and has a stage at *l*.

Another modification, which produces a very pure tallow, is described under Butterine (p. 1362). Its disadvantages are the necessity for the comminution of the fat, and the length of time required by the process, i. e. the large amount of plant necessary to "render" a few tons of rough fat. Its advantages are the almost complete freedom from noxious vapours (hence it is strongly recommended by Dr. Ballard), and the great purity of the product.

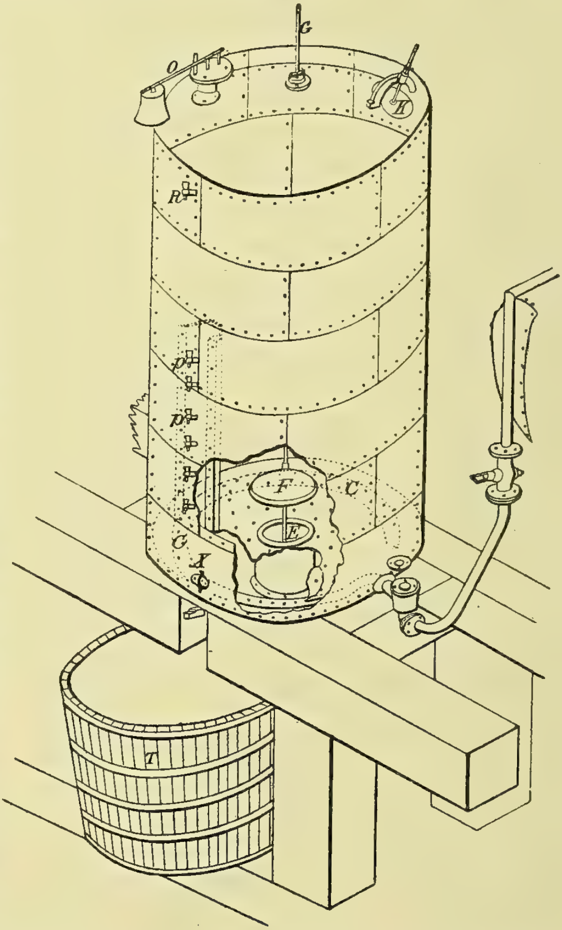
1022.



When the saving of the animal tissue is a matter of no moment, it is better to "render" the fat in the presence of water and steam. This can only be completely done under slight pressure (boiling the comminuted fat upon water in an open vessel only extracts part of the tallow, &c.), and is most suitably effected in a vessel such as that shown in Fig. 1023. The apparatus consists of a series of steam-tight cylinders of 1200–1500 gal. capacity, formed of boiler-plate, with a length about 2½ times greater than the diameter, and provided with false bottoms. The operation proceeds thus:—The cylinder is fed through the man-hole K with crude fatty matters to within about 2½ ft. of the top. The man-hole is secured, and steam is admitted by the foot-valve into the perforated pipe C. The safety-valve O is set at the required pressure, and frequent testing of the state of the contents of the cylinder is made by opening the try-cock R. An excess of condensed steam in the cylinder will be indicated by the spurting ejection of the fatty matters, when the regulating-cock X must be opened, and the condensed steam be drawn off into the tub T, till the escape of fatty matter from R has ceased. After 10–15 hours' continued steaming, the steam is shut off, and such as remains uncondensed in the cylinder is let out by the try-cock and safety-valve. After due rest, the fatty matters separate out and form the uppermost layer, and are drawn off through the cocks *p* into ordinary coolers. The fat being emptied from the cylinder, the cover F is raised by the rod

G from the discharging-hole E, and the residue falls into the tub T. Should the residue retain any fat, it is returned to the cylinder with the next charge. The pressure of steam commonly used is 50–75 lb. a sq. in., sometimes advancing to 100 lb., though this last figure is excessive, and calculated to injure the quality of the fat by decomposing the animal matters present. The yield obtained is considerably greater than by the ordinary methods, being stated at 12 per cent. extra for lard, and 6 per cent. for tallow. On the other hand, it is almost necessary to wash the fat with fresh water, and remelt and settle it, to remove the last traces of animal matter held in suspension by the unseparated water, and having a tendency to putrefy.

1023.



Another modification of the steam process is to subject the rough fat to the action of about ¼ its bulk of water, containing 2–3 per cent. of sulphuric acid, boiling the whole by steam at atmospheric pressure, i. e. in an open, or loosely closed, lead-lined tank. There exists, however, a prejudice against tallow or lard in whose preparation any chemicals have been used.

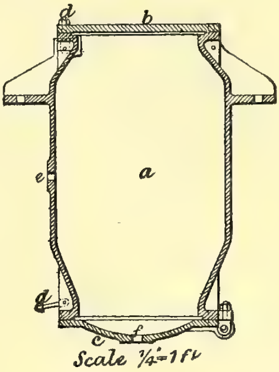
In all cases, it is highly desirable to render the fat as soon as possible after its removal from the animal's body, since the animal tissue rapidly decomposes, and sets up fermentation, producing rancidity in what would otherwise be a neutral fat, and also injuring the colour, &c., of the ultimate product. The different kinds of fat should also be sorted, and each description melted separately. In large establishments, such as the Union stockyards of Chicago, the stockyards at St. Louis, and the packing-houses of Cincinnati, where thousands of beasts are killed every day, there is a row of these digesters, each one allotted to its own kind of fat, which is placed therein a few minutes after the death of the animal. In this way, is secured great uniformity in the various grades of tallow and lard produced. The waste liquor, containing large quantities of nitrogenous matter, is sold for manure.

Many soap-makers "render" rough fat in a soap-copper (see Soap) by the simple action of wet steam upon it, while the cover of the copper is secured by bolts or weights. When all the tallow has been skimmed off, a weak impure solution of caustic soda, technically known as "half-spent leys," is run in, and the whole is boiled. The object is to saponify the last remaining portions of tallow, and the discoloured imperfect soap is used in lower grades of the pure article. The process, however, is a wasteful one, since large quantities of the soda are used up in forming ammonia, by its action upon the nitrogenous animal tissue, and this ammonia, being volatile, escapes with the noxious vapours, and thus a valuable fertilizing agent is lost. As far as concerns the avoidance of noxious odours, rendering by steam has undoubted advantages, and it is altogether a more rapid and satisfactory process.

The foregoing descriptions of the various processes for the "rendering" of beef-, mutton-, and pig- fat, apply equally, *mutatis mutandis*, to that of kitchen-stuff, ship's-grease, &c. In these cases, however, the liability to rancidity, and production of noxious fumes, is much greater than with fresh fat.

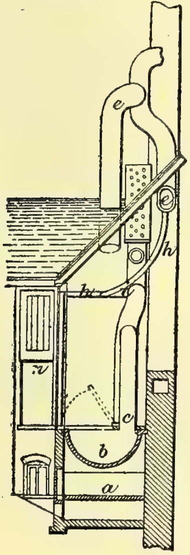
A large quantity of fat, known as "bone-fat," "bone-grease," or "bone-tallow" is now extracted from bones, and is chiefly used by the soap-maker. The common method of extracting the fixed fat from bones by boiling in open vessels has been described under Manures (p. 1256). A great improvement consists in the application of steam in closed vessels, as adopted by most large firms. The form used by Morris and Griffin, at Wolverhampton, is shown in Fig. 1024. It is composed of a $1\frac{1}{8}$-in. iron cylinder *a*, 6 ft. long by 3 ft. 6 in. in greatest diameter, furnished with hinged doors *b c* at top and bottom, which are tightly closed during operations by $1\frac{1}{4}$-in. screw-threaded bolts and nuts *d*, and further provided with 2-in. tap-holes at *e* and *f*. The bones are introduced at the top door *b*, which is then secured; steam at about 141° (286° F.) is introduced for 40 minutes; the steam is shut off, and that remaining in the cylinder *a* is let out into a condenser; ½ hour later, the fat is drawn off by the tap *f* at the bottom of the cylinder; the bottom door *c* is then opened, and the bones are allowed to fall upon the floor below. The bones are rendered much more brittle than by ordinary boiling, and are much drier and more easily ground, requiring no previous storing (see Manures, p. 1256). The cylinder shown will steam at a charge 46½ cwt. of bones, yielding 87–88 lb. of fat per ton.

1024.

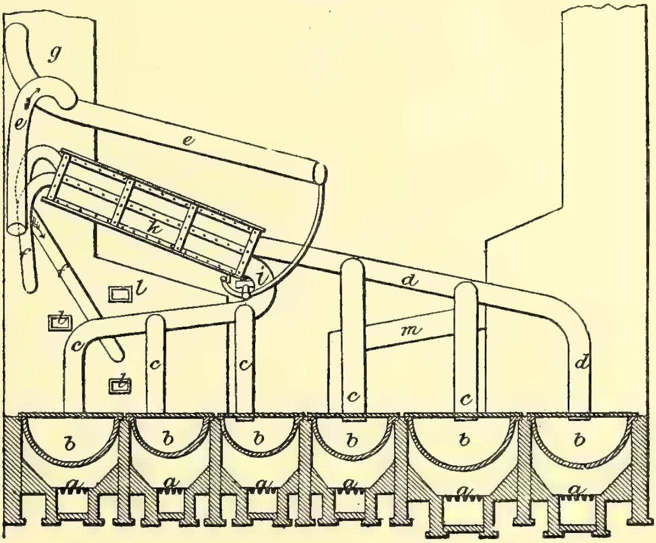


One of the best and most inoffensive arrangements of the bone-boilers for a large establishment is that adopted at Adams' knackery, in Birmingham, erected under the direction of Dr. Alfred Hill, and shown in Figs. 1025, 1026. A set of six pans are set and heated in the usual way. They are enclosed above in a sort of closet, formed by a wooden partition, reaching up to the roof of the building and down to the front of the top of the pans. Opposite each pan, is a shutter in the partition, which can be slid up whenever it is requisite to obtain access to the pan. Each pan is closely covered with a wooden lid, and from the upper and back part of each pan, beneath the cover, starts a pipe leading to a 10-in. main running the whole length above the pans and within the hopper, receiving contributions of vapour from each pan. This pipe finally has exit outside the building; it here communicates with an oblong condenser, made of sheet iron, filled with coke, measuring 14 ft. long, 3 ft. in vertical section, and 14 in. in horizontal section, inclined a little in its long diameter. At the lower end, it receives the pipe from the boilers; and from its lower border, another small pipe conveys away the water produced by the condensation of the vapour, the cooling agent being the outer air, to which the condenser is exposed on all sides. The upper end of the condenser communicates by two air-pipes with the flues from the fire-places. When the pan-lids are raised, the escaping vapour rises to the roof, and is conveyed from the interior of the closet into the chimney-shaft, by escape-steam pipes provided for the purpose. The reference-letters indicate: *a*, fire-holes; *b*, boiling-pans; *c*, steam-pipes; *d*, main steam-pipe; *e*, escape-steam pipes; *f*, air-

1025.



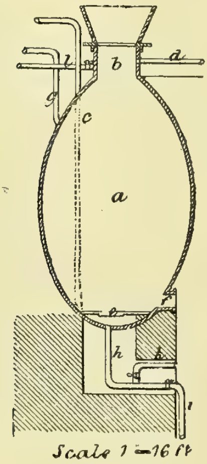
1026.



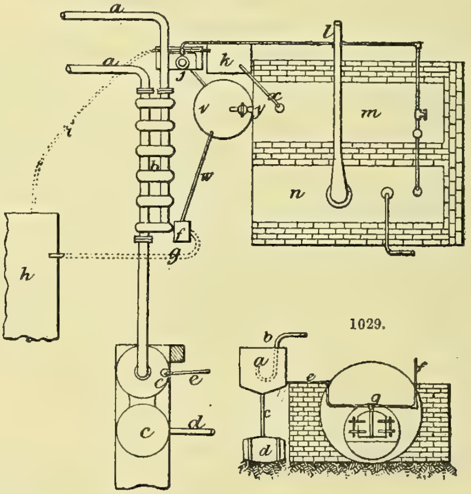
pipes; *g*, chimney-shafts; *h*, condensed-steam pipes; *i*, water-trough; *k*, wrought-iron condenser; *l*, doors for cleaning smoke-flues; *m*, smoke-flues; *n*, closet with sliding door.

The form of digester employed by Proctor and Ryland, of Birmingham, for extracting both fat and gelatine from bones, is shown Fig. 1027. It consists of a (duplicate) egg-shaped iron vessel *a*, capable of holding 6–7 tons of bones; at the upper end, is a short neck *b*, surrounding the charging-hole, which is closed by a tight-fitting cover; here enters the steam-pipe *c*, which descends to the bottom of the digester, here also the waste-steam pipe has its exit. At the bottom of the digester, is a wooden false bottom *e* for supporting the bones, and on one side is a man-hole *f* for reaching the false bottom and removing the boiled bones. Cold water can be introduced by the pipe *g*. The liquid matters are withdrawn by the pipe *h*, separating into two branches, with appropriate taps the one *i* leading to a drain, the other *k* to a tank. The bones are first boiled in water by the admission of free steam; when sufficiently boiled, steam is turned off, and time is allowed for the fat to separate; cold water is then let in by *g* to raise the fat to the level of the pipe *l*, when it escapes into a receptacle. The water is next run off from the digester by the pipes *h i* into a drain, the top cover is fastened down again, and the bones are steamed at a pressure of about 50 lb. for the extraction of the gelatine; the gelatine is drawn off by the pipes *b k*, and the bones are finally removed by the man-hole *f*. The bones are in a less friable condition than when the form shown in Fig. 1023 is used, and they require to heat somewhat before being ground.

1027.



1028.



1029.

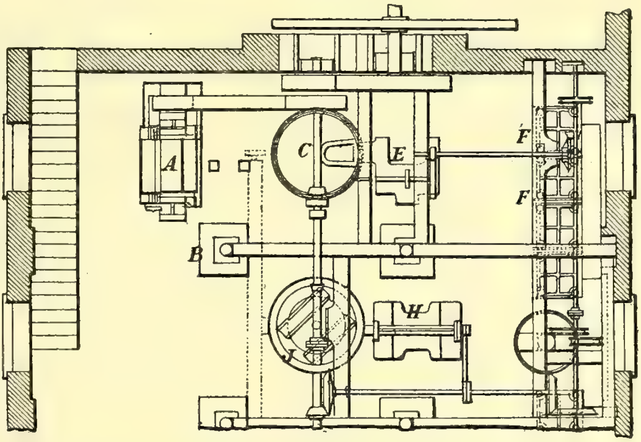
(For a further and desirable process of purification, see Refining, p. 1460.)

The calcining of bones has been described under the article Blacks—Bone-black, p. 453. One of the best arrangements for separating bone-oil from the other products of the distillation is shown in Fig. 1028. The pipes leaving the retorts first ascend, then bend downwards into a wide iron pipe, running horizontally about 1 ft. above the retorts, and containing water. Here the first condensation takes place. The vapours next pass by the pipes *a* to a continuous condenser *b*, such as is used in gas-works, and exposed to the outer air. Passing hence, the vapour, still containing condensable matters, is conducted through two coke scrubbers *c*, fed by a pipe *e* with trickling streams either of water, or of ammoniacal liquor, raised by the pump *j* from the well *k*, which receives it from the scrubbers, the liquor being thus made to circulate till it is sufficiently strong. The washed gas escapes at *d* for further treatment elsewhere. The liquors from the condenser *c* are received in *f*, where the first rough separation of bone-oil and ammonia-liquor takes place, the former floating while the latter sinks. The oil flows away at the surface by the 1-in. pipe *w* to a barrel *v* sunk in the ground; the liquor escapes by the larger pipe *g*, which is bent siphon-like, and dips into the liquor below the oil, the top of the siphon being at the same level as the pipe that carries off the oil. The liquor is conveyed to the receiver *h*. It still contains much oil, which is more completely separated by pumping the whole through the pipe *i* into a subsiding-vessel *m*, provided with taps as at *y* for drawing off the oil at intervals into *v*, while the liquor is pumped out through the pipe *x* (reaching to the very bottom of the tank) and pipe *l* into the still *n*. Its further treatment does not come within the scope of this article (see p. 232). The oil in *v* contains some ammonia worth recovering. It is therefore raised by the pump *j* into a tank *a* (Fig. 1029) above *b*, and the ammonia is washed out by injecting steam through the perforated pipe *b*; the liquor collects at the bottom, and is drawn off by *c* into a barrel *d* for conveyance to *n* or *h*.

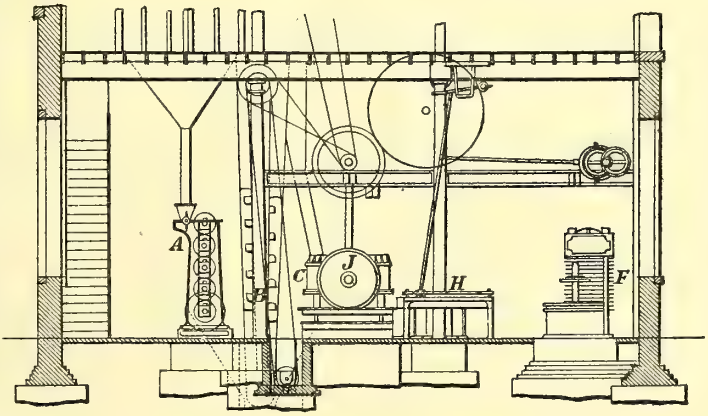
The oil is variously dealt with. At some works, it is barreled and sold; at others, it is mixed up with manures, or used as fuel. In the last case, it is pumped into *a* (Fig. 1029) and conducted by the pipe *e*, as wanted, to the boiler fire, into which it is showered by a steam-jet issuing from *f* at *g*, at right angles to the opening of *e*, at the furnace-mouth. This seems to answer the desired end very well. As the oil resembles mineral oil in some of its characteristics, it does not saponify readily, if at all, and is chiefly valuable as a coarse lubricant.

Vegetable Fixed Oils and Fats.—A detailed account of oil-mill machinery will be found in Spons' Dictionary of Engineering, p. 2482. It is here proposed to supplement it by the addition of such modern improvements as have since come into use. The class of machinery there shown in Figs. 5907 and 5908 is being rapidly replaced by the system introduced by Rose, Downs, and Thompson, of Hull, in 1874. Indebtedness is acknowledged to this well-known firm for the subjoined descriptions and illustrations of improved apparatus for extracting the oil from various oleaginous seeds and nuts, and converting the pulp into cake for feeding cattle.

1030.



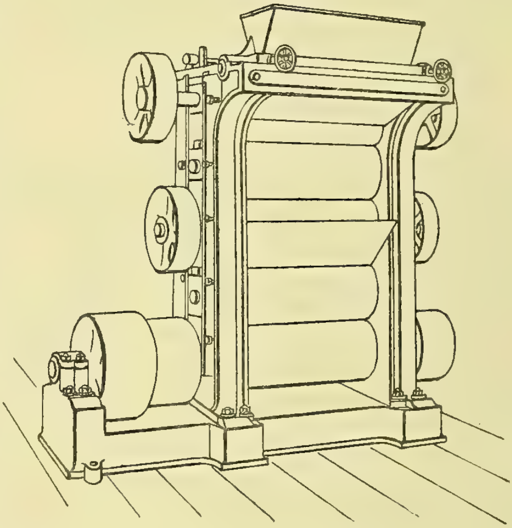
1031.



The arrangement of the mill is shown in plan in Fig. 1030, and in elevation in Fig. 1031. The seed or other material passes through the following course:—It runs from an upper floor through the roll-frame A, by which it is crushed 3 or 4 times; it is then taken by the elevators B to the kettle C, where it is heated and damped. From beneath the kettle, it is drawn, in quantities sufficient to make a cake, by a box which conveys it to the moulding-machine E. Here it undergoes preliminary compression, the objects of which are (1) to increase the number of cakes which may be inserted in the presses at one time, enabling 18 12-lb. cakes to be made where 4 8-lb. cakes were formerly made, and (2) to ensure uniform size and weight, and uniform density or consistence throughout. The cakes are removed from the moulding-machine, and put into the press F, 3 or 4 of which are required to each moulding-machine. The pressure is applied either by means of hydraulic pumps, or by a high-and-low-pressure accumulator; but unless extreme care is used with the latter, it gives too rapid a pressure, squirting out the seed at the side of the plates, and exercising a destructive effect upon the cloth employed. The pulsation caused by the pumps working directly to the press-cylinder is more akin to the action of a wedge, and seems to extract the oil better than the dead pressure given by the accumulator. If the latter is used, a small cylinder may be applied to give the preliminary pressure in the moulding-machine, in lieu of a cam. After remaining under pressure about 25 minutes, the cakes are withdrawn, and after being stripped of the cloth, are pared by the machine H, which completes the manufacture of the cakes. The parings fall under a very small pair of edge-running stones J, which automatically discharge them, when sufficiently ground, into an elevator conducting to the kettle, where they are worked up with fresh seed. In a mill with 4 presses, 2 men and a boy in the press-room can make 6 tons of cake in 11 hours, a rate of production requiring 6 men by the old process. The saving in steam-power is about 30 per cent., chiefly due to the absence of the heavy edge-runners, which also effects an economy of space. About 2 per cent. more oil is extracted, and the cakes are improved in appearance by not having the structureless texture caused by the trituration of the seed under edge-runners.

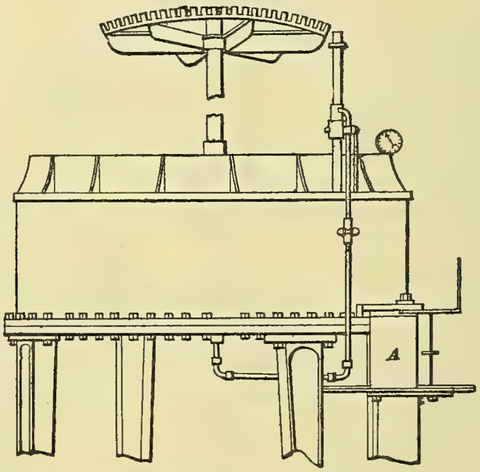
Having described the general routine of the process, some details may be added concerning the working of the several machines. The roll-frame Fig. 1032, consists of 4 or 5 chilled-iron rolls, each 3 ft. 6 in. long by 16 in. in diameter, placed one above the other. These rolls are used for crushing all the seed that passes through one set of presses making $5\frac{1}{2}$–$6\frac{1}{4}$ tons linseed-cake per spell of 11 hours. The seed passes into the hopper in the usual manner, and is distributed to the crushing-rolls by a fluted feed-roll the same length as the crushing-rolls, placed at the bottom of the hopper. When the seed passes the feed-roll, it falls on a guide-plate that carries it between the 1st and 2nd roll. After passing between these rolls and being partly crushed, it falls on a guide-plate on the other side, which carries it back between the 2nd and 3rd rolls, where it is crushed more fully. It then falls on another guide-plate, which carries it between the 3rd and 4th rolls, where it is ground more fully; then it falls on a 4th guide-plate, and is conveyed between the 4th and 5th rolls to receive the finishing touch. It is thus crushed four times.

1032.



The kettle is shown in Fig. 1033, which represents one capable of heating sufficient seed to keep 4 16-plate presses occupied, or to make 6 tons of cake per 11 hours. It is steam-jacketed and furnished inside with a damping-apparatus. The inside diameter is 5 ft., and the depth 2 ft. 6 in. The seed introduced is kept in motion by the stirring-gear, and when sufficiently heated and damped, is withdrawn by the box A in quantities to form one cake, and transferred at once to the moulding-machine, attached or separate.

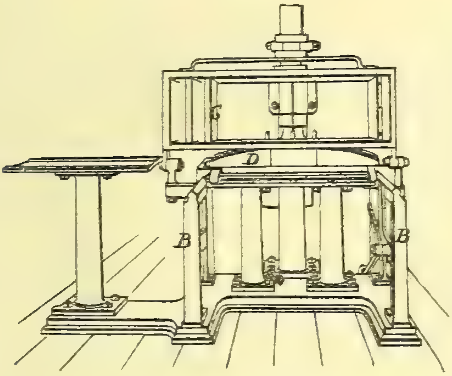
1033.



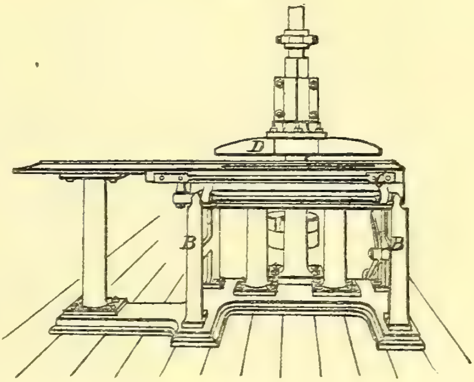
This machine is illustrated in Figs. 1034, 1035. Its purpose is to measure the quantity of seed required to make each cake, to shape it as required, and to press it so much, without extracting any oil, as will enable the greatest number of cakes to be put into the press. The measure of seed is placed on a strip of woollen cloth, spread upon a thin iron tray, sliding on the guides B; the bottomless hinged mould C, having the exact shape of the intended cake, is closed upon it, and the measure A (Fig.1033), which is also bottomless, is drawn over guides in the upper surface of the mould C, thus accurately distributing the seed. The mould is next thrown upon its hinge (Fig. 1034), and the ends of the strip of cloth are folded over the seed, the thickness of which is about $3\frac{1}{2}$ in. The thin iron tray, with the mould of seed upon it, is then pushed along the guides B, beneath the die D. This action gives motion to a cam, shown above in the illustrations, but which may be placed beneath if necessary. This cam brings down the die, and compresses the mould of seed to a thickness of 1¼ in.; its revolutions are so timed that the seed is under pressure long enough (about ⅓ minute) to let the workman have another cake ready.

When the die of the moulding-machine rises, the cake and tray are removed and placed in the press (Fig. 1036), the tray being withdrawn. The plates of the press are slightly thickened towards the edges, and bear the name of the manufacturer in reverse. The press is suitable for extracting oil from linseed, rape-seed, cotton-seed, hemp-seed, niger-seed, sunflower-seed, gingelly-seed, castor-seed, ground-nuts, coco-nuts, olives, &c. It is made in various sizes. The No. 1 double press (not shown) is furnished with 4 cake-boxes, suitable for making 4 tapered cakes at one pressing, each about 2 ft. 5 in. long, by 10½ in. wide at one end, and 7½ in. at the other, when using linseed, 48 lb. of Bombay seed being required to charge the press, and giving a cake weighing about 8 lb.; the maximum and minimum weights of its charges are 60 lb. and 40 lb., of the cakes, 13 lb. and 6½ lb. The charges vary from 3 to 6 an hour, being 4 for cotton-seed and 5 for linseed; most other seeds are worked the same as linseed, but rape and gingelly are worked twice. By using 2 presses for the first time and 3 for the second, 3 presses will crush as much seed as 5. These presses are made of a capacity to take 270–320 lb. seed at a charge, giving cakes of 9–15 lb., and requiring 30–45 minutes for the operation. In all these presses, the hair wrappers, weighing some 26 lb., used in the old process, are dispensed with.

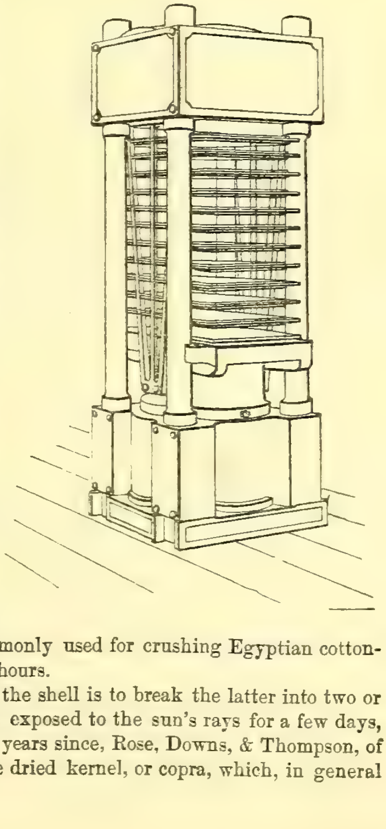
1034.



1035.



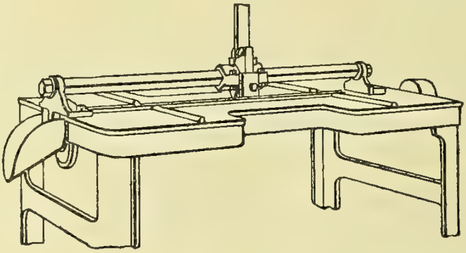
1036.



After being sufficiently pressed, the cakes are withdrawn, stripped of their cloths, and pared by the machine shown in Fig. 1037, which consists of 2 reciprocating knives moving above a table fitted with guides and gauges, and with a screw conveyer in the centre, for discharging the parings at one end. Two boys attending the machine can pare 12–13 tons a day. The parings are taken under a very small set of edge-runner mill-stones, which automatically discharge them, when sufficiently ground, into an elevator leading to the kettle, where they are worked up with fresh seed. Larger edge-runners are very commonly used for crushing Egyptian cotton-seed; a set weighing 404 cwt. crush about 6 tons per 11 hours.

The ordinary method of liberating the coco-nut from the shell is to break the latter into two or more pieces by blows from a hammer, and to leave these exposed to the sun's rays for a few days, when the kernel contracts, and leaves the shell. Some years since, Rose, Downs, & Thompson, of Hull, designed two machines for slicing and rasping the dried kernel, or copra, which, in general construction, resembled gigantic mincing-machines. The slicing-machine worked well, and turned out a large quantity, but it was found to be of little value in practice, on account of the frequency with which stones and similar foreign bodies got mixed among the copra, and injured the knives. The rasping-machine also suffered in a minor degree from the same cause. Moreover, there was no real gain in using the machines, as they did not reduce the material to a sufficiently fine degree. The first produced thin slices, and the second rendered these granular only, like coarse sawdust, so that it was still necessary to pass the material through an edge-runner mill, and no perceptible difference was made in the amount of grinding required in this latter. Consequently, both machines have been abandoned, and the broken copra is thrown at once under edge-runners, and then pressed and dealt with much in the same manner as an ordinary oleaginous seed. The firm named estimate the average cost of the machinery adapted to a small mill capable of treating about 40 cwt. of copra daily, and making 24–25 cwt. of oil, and 15–16 cwt. of cake, as follows:—Engine, boiler, edge-runners, presses, pumps, gauges, "hairs," cisterns, pipes, nuts, bags, bagging, and all fittings complete, at about 1000*l.* The same motive power will drive also the machinery for preparing the fibre from the husk, costing about 150*l.* additional.

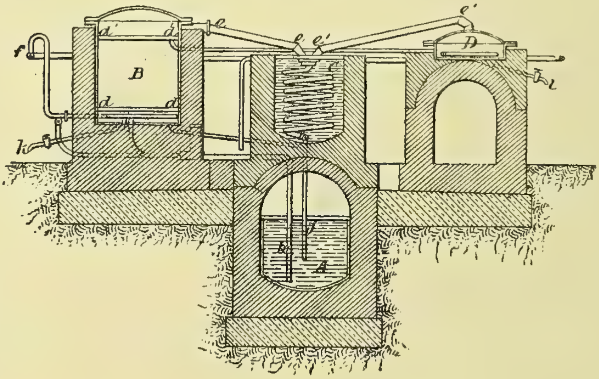
1037.



Not unfrequently, in order to extract the last traces of fat or oil from seeds and nuts, recourse is had to the solvent action of carbon bisulphide. This plan is adopted on a very large scale by Heyl, of Berlin, and by Sevin, of London, for the manufacture of palm-kernel-oil; and so completely is the meal freed from all traces of carbon bisulphide and its attendant nauseous-smelling compounds, that it is much used for cattle-food, though less valuable for that purpose than the meal from simple expression, by reason of its deficiency in oil. The residues from the extraction of olive-oil in S. Europe are dealt with in the same way, and made to yield an additional 2–4 per cent. of the so-called "pyrene" oil.

The method of employing carbon bisulphide may be illustrated by Figs. 1038 and 1039, showing respectively a longitudinal section and plan of Deitz's apparatus. It consists of extractors B, which are usually worked in couples alternately, and in connection with a still D, containing a steam-coil, and communicating with a cooler C by means of a pipe *e′*. The pipe *j* leads from the cooler-worm to a receptacle A for storing the bisulphide. The extractor B is also connected with the cooler C by the pipe *e*, and provided with suitable openings for the introduction and withdrawal of the fatty matters. These latter are put into B between two perforated plates *d d′*; bisulphide is pumped from A by the pipe *h* in at the bottom of B. The bisulphide passes up through the mass, absorbs the fat present, and escapes finally by the pipe *f* to the still D. The admission of bisulphide is continued till a sample drawn off at *k* is free from fat. The bisulphide is then shut off, and steam is injected into the extractor through a perforated coil lying between the bottom and the perforated plate. The remaining bisulphide is thus carried by the pipe *f* into the receptacle A. The fat-saturated bisulphide is distilled in D, by means of a steam-coil. The evaporated bisulphide liquefies in the cooler C, and runs back into A for further use. Steam is occasionally passed through the fat, to completely free it from bisulphide; and the clean fat is finally let out by the pipe *i*.

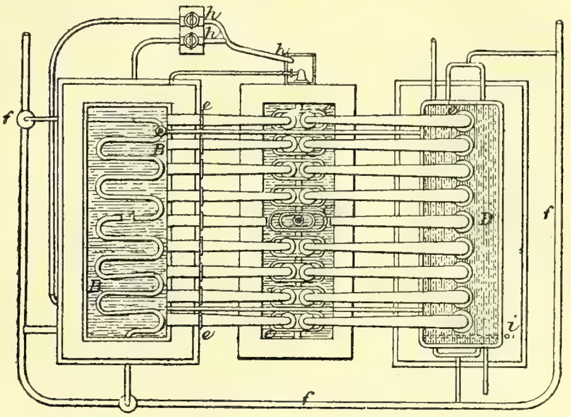
1038.



In America, preference is given to petroleum-spirit of low boiling-point, as being cheaper and less dangerous, though less rapid in its action. The materials there principally dealt with are the residues from the rendering of animal fats (as tallow and lard), containing 12–15 per cent. of extractable grease. The patents relating to this industry in America are very numerous, but those taken out by Adamson seem to be most largely adopted. The process lasts 24–36 hours, and the products are used mainly as lubricants, being unfit for making good soap. "Pomace" or castor-cake, and greasy cotton-waste, are similarly treated.

A very great disadvantage of petroleum-spirit, however, is that whereas the high sp. gr. of carbon bisulphide enables it to be kept covered with water (and even collected from the mouths of the condenser-worms under water), and thus protected from all risk of explosion by contact of its vapour with air and flame, petroleum-spirit, which is, bulk for bulk, about half as heavy as the bisulphide, cannot be so protected from accident and loss by evaporation. Its vapour-density also is much less.

1039.



Recovery of Waste Grease.—A description of the means suited to the recovery of grease from fabrics and liquids which have served their purpose may fitly be introduced here.

In the recovery of oil from oily cloths, the latter are first soaked with water and soda crystals in a tub, and steam is thrown in; the mixture of alkaline water and oil thus obtained (the latter saponifies to a slight extent), is run off into an open tank; this operation is repeated as often as appears necessary. The cloths are then squeezed nearly dry between rollers; the liquor is received in a tank, where it accumulates, and separates on standing, the oil collecting on the surface, while the dirty water remains below. The oil is ladled out into casks, and used for making blacking, or refined for other purposes. The cloths are finally dried by suspension in a chamber heated by coke fires in braziers. Offensive odours are generated, and the whole arrangement should be enclosed, and provided with means for conveying the vapours into a tall chimney.

The recovery of grease from the waste shoddy of woollen-mills, from cotton waste used for wiping oily machinery, from scrapings from fat-melting establishments, and in short from almost any mixed mass of grease and other matters, is now effected on a large scale by means of carbon bisulphide. The method of applying this solvent now generally adopted is to introduce the greasy matter very lightly and loosely into an airtight iron cylinder provided with a false bottom, taking care to ensure the porosity of the mass, and its freedom from more than a very small percentage of water. The bisulphide, pumped in from below, because it diminishes in sp. gr. as it dissolves the fatty matters, rises through the cylinder, dissolves out the grease, and flows away at the top into a still. It is then distilled off by steam, and condensed, running with the condensed steam into an underground reservoir, where it lies covered with water till required again. The greasy matters are left in the still, whence they can be drawn off. When all the grease has been extracted from the material, the bisulphide retained by the latter is drained off; the injection of free steam then drives off the last traces of bisulphide into a condensing-worm, and thence to the underground reservoir. The loss of solvent in each operation is trifling, but the most stringent precautions are necessary to prevent leakage. An arrangement of this character has been described and illustrated under Carbon Bisulphide (see pp. 605–6, Fig. 473).

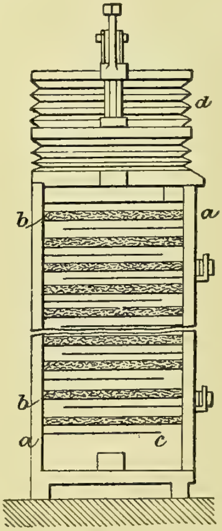
Soap-suds contain a large quantity of fat combined with alkali as a soap. The recovery of this fat is now largely accomplished, especially in the woollen-manufacturing districts of England, from the suds leaving woollen-mills, which contain, in addition to the soap employed in washing or fulling the wool, a large quantity of fat derived from the wool itself. These are first carefully strained and then settled to remove extraneous matters. From the settling-tank, the liquid flows into several large tanks, where, in succession, the "breaking" or decomposition of the soap is effected. Steam is first injected to raise the temperature to about 49° (120° F.), and sulphuric acid is then added, in such proportion as to leave the (broken) liquor feebly sour to the taste. This preliminary heating is not adopted in all cases, as the same end (the facilitation of the breaking) is attained by keeping the suds for 3–4 days. But this is a most objectionable proceeding, on account of the offensive putrefactive odours emitted; it also requires the provision of much additional storage room. In the breaking, the acid combines with the soda, and liberates the grease, which partially floats, and partially settles to the bottom of the tank with earthy and other impurities. Time is allowed for the complete separation of the grease; the liquid is then run off through drains, and the scum or "magma" is put into canvas filters on wooden frames. From these, the liquid portion escapes into the drains, and a blackish-grey greasy mass remains upon the filters. This mass is wrapped up in cloths, and first subjected to cold expression to free it completely from water. To recover the grease, the packages, as they leave the cold press, are transferred to a hot press, where steam is introduced at ordinary pressure. The grease is thus melted out, and, with condensed water and some dirt, escapes at the bottom into a sunken tank, about 2 ft. long, 1½ ft. wide, and 3 ft. deep. Here the oil separates from the dirty condensed water, floats, and is ladled out while still liquid. The dirty water is let out at intervals into a large underground tank, where more grease separates. The oil ladled out is transferred to a lead-lined vessel, and treated with strong sulphuric acid to remove any water that may be in it, after which, it is barrelled for sale. The residue in the hot press, called "sud-cake," is treated with carbon bisulphide to extract any remaining traces of grease, and is then used for manure-making. The waste liquor, neutralized with lime, or made slightly alkaline, may be beneficially used for irrigating pasture.

Essential Oils.—The extraction and recovery of vegetable essential oils is performed by the following processes.

Enfleurage.—The simplest and most important of the processes adopted for recovering the perfumes of plants for industrial purposes is known as absorption or *enfleurage.* The earliest and most primitive method of performing this consists in allowing the flowers to lie between glass plates covered on both sides with grease, and superposed in piles in a frame, the flowers being renewed every day during the season, which may last for 8 days or 3 months. In absorbing by means of oil, instead of solid grease, the glass plates are replaced by frames of wire-gauze, covered with pieces of linen soaked in olive-oil, between which the flowers are spread and renewed as in the other case. The oil is squeezed out by the gentle action of a screw press. These primitive plans are still in wide use, despite their cost for labour, their slowness, and the risk of the absorbent grease becoming rancid.

A great improvement is the pneumatic method introduced by Piver, and illustrated in Fig. 1040. The apparatus consists of a box *a*, about 10 ft. high and 6 ft. wide, containing wire-gauze trays *b* for holding the flowers; between them, sheets of glass or silvered copper *c*, fixed at one side, but free on the three edges, receive the grease, not only in a flat layer, but divided into extremely fine drops, by being forced through a plate penetrated with minute holes. Two bellows *d*, arranged so that one falls while the other rises, maintain a current of air throughout the apparatus, by which the grease is rapidly impregnated without the flowers coming into actual contact with it, thus avoiding the destruction of the perfume and staining of the grease, often arising from fermentation of the flowers in the presence of animal matters.

1040.



More recent improvements in the conduct of the absorption-process have been in the direction of replacing the grease by some neutral substance, such as paraffin, glycerine, and vaseline. In order to remove all traces of the paraffin from extracts obtained by its agency, it is recommended to subject them to a freezing-mixture, in order that all the stearoptene of the flowers may be deposited. Glycerine, concentrated and inodorous, has been proposed by Rimmel as superior to paraffin, on account of its fluid condition. Vaseline or cosmoline, extracted from petroleum residues, presents a great analogy to paraffin, except in having a consistence nearer that of glycerine. Vaseline has several advantages, and has been largely used; it very readily absorbs the odours of those flowers which can be treated by heat. But there are many flowers which cannot be so treated, and it has been found that the alcoholic extracts made from impregnated vaseline rapidly lose their odour, even at the end of a month. On the whole, it is probable that the application of vaseline to *enfleurage* will be far less wide than was at first supposed.

Solvents.—The extraction of essential oils by means of solvents consists of three successive operations;—(1) Solution of the oil by passing the solvent over the flowers placed in a percolator; (2) distillation at a low temperature of the liquid obtained, to remove the wax mixed with the odoriferous body; (3) evaporation of the last traces of the solvent in a water-bath. The solvent may be ether, chloroform, carbon bisulphide, petroleum-spirit, &c. Prof. Vincent, in combination with a perfumer named Massignon, has adopted chloride of methyl as a solvent for extracting essential oils, the chloride being previously treated in the gaseous state with concentrated sulphuric acid, to remove malodorous impurities. The oil-yielding body (flowers, &c.) is repeatedly digested for 2 minutes with charges of liquid chloride in a close vessel, the impregnated chloride passing into a receiver; finally all traces are pumped from the digester into a vessel where the chloride is liquefied by cold compression; a jet of steam is passed through the exhausted mass of flowers to drive out the chloride retained by the traces of water in the flowers. The liquefied saturated chloride is evaporated *in vacuo*, leaving the essential oil in the waxy and fatty residues. The essential oil is removed from the mass by treatment with cold alcohol. Apparatus capable of dealing with 1 ton of flowers daily has been erected on this principle at Cannes, S. France.

In America, Prof. Seeley's method of applying gasoline as a solvent of essential oils has been largely used for extracting the valuable principle of hops.

Expression and Scarification.—Such processes as are described in this section are adapted only to materials yielding a large proportion of essential oil, such as the fruits of the *Citrus* genus. The simplest form is the so-called "sponge-process." The peel is first cut off the fruit in 3 thick longitudinal slices, leaving the central pulp of triangular shape, with a little peel at either end; the central pulp is cut transversely in the middle, and thrown on one side, while the peel is collected on the other. The latter is left till next day, then treated thus—A seated workman holds in the palm of his left hand a flattish piece of sponge, lapped round his fore-finger. With the other hand, he places a slice of peel upon the sponge, the outer surface downwards, and presses the uppermost (zeste-) side, so as to give it a convex instead of concave surface. The oil vesicles are thus ruptured, and the oil which issues from them is absorbed by the sponge with which they are in contact. Each slice receives 4–5 squeezes, and is then thrown aside. The workman carefully avoids pressing the small bit of pulp attached to each slice. As the sponge becomes saturated, it is forcibly wrung out into a coarse earthenware bowl, provided with a spout, and of a size to hold at least 3 pints; here the oil separates from the watery liquid accompanying it, and is decanted. Despite its apparent rudeness and wastefulness, this process is capable of affording an excellent article; it is employed chiefly for treating lemons.

Another implement adopted with both lemon and bergamot is known as the *écuelle à piques*. It is a stout pewter saucer, about 8½ in. wide, with a lip on one side for convenience of pouring. The bottom is covered with stout, sharp, brass pins, standing up about ½ in., the centre being deepened into a tube about ½ in. in diameter and 5 in. long, closed at the lower end. The whole resembles a shallow funnel, with the tube stopped up at the end. The peel is held in the hand, and rubbed over the pins, by which the oil-vessels of the entire surface are punctured; the liberated oil flows down into the tube, which is emptied at intervals into another vessel, where the oil may separate from the turbid watery liquid accompanying it.

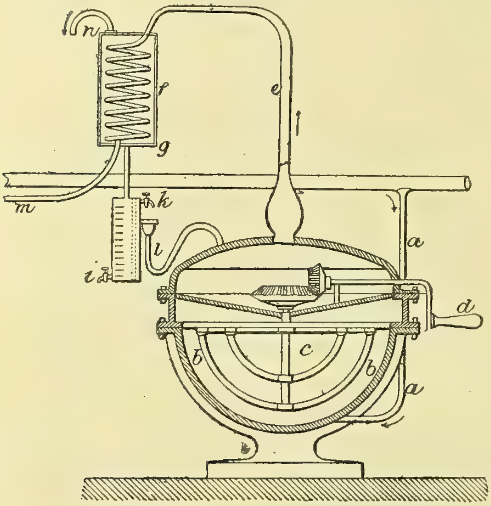
A modified form of the *écuelle*, for extracting bergamot-oil from the full-grown, but unripe, entire fruits, is constructed as follows. The fruits are placed in a strong metallic dish, about 10 in. wide, having a raised central opening, forming with the outer edge a broad groove or channel, and covered with a lid of similar form. The inner surfaces of both dish and lid are provided with a number of narrow, radiating, metallic ridge-blades, about ¼ in. high, and resembling knife-backs. The dish is also perforated to permit the outflow of the oil, and both dish and lid are arranged in a metallic cylinder, placed over a vessel to receive the oil. By a simple set of cog-wheels, a handle causes the cover, which is very heavy, to revolve rapidly over the dish; the fruit lying between the two is carried round, and simultaneously subjected to the action of the sharp ridges, which, rupturing the oil-vessels, set free the oil to flow out by the small holes in the bottom of the dish. Some 6-8 or more fruits are dealt with at once, and are kept under operation for about ½ minute; about 7000 fruits can thus be treated in one such machine per diem.

Distillation.—The oleiferous material is placed in an iron, copper, or glass still, of 1–1000 gal. capacity, and is covered with water; superposed is a dome-shaped lid, terminating in a coil of pipe, placed in a vessel of cold water, and protruding therefrom with a tap at the end. On boiling the contents of the still, the essential oil passes over with the steam, and is condensed with it in the receiver; the oil and water separate on standing. A great improvement, introduced by Drew, Heywood, and Barron, is the use of a steam-jacketed still, as shown in Fig. 1041. Steam is supplied from a boiler by the pipe *a* into the jacket *b*; within the head of the still, is fixed a "rouser" *c*, a double-branched stirrer curved to the form of the pan, and having a chain attached and made to drag over the bottom, the whole being set in motion by means of the handle *d*. The still is charged, and nearly filled with water; the head is then bolted on, steam is admitted into the jacket, the contents are well stirred, and soon the oil and steam are carried up the pipe *e*, condensed in the refrigerator *f*, and let out at *g* into the receiver *h*. Here the oil and water separate, and escape by different taps. In the illustration, it is supposed that the oil obtained is heavier than water; it will then sink, and be drawn out by the lower tap *i*, and, as soon as the water reaches the level of the upper tap *k*, it will flow into the syphon-funnel *l*, and thence into the still. Thus the same water is repeatedly used in the still. The pipe *m* conveys cold water into the refrigerator *f*; the water escapes as it becomes hot by the pipe *n*. When the oil distilled is lighter than water, the taps *i k* exchange duties. Before commencing operations, the siphon *l* is filled with water to prevent the escape of vapour.

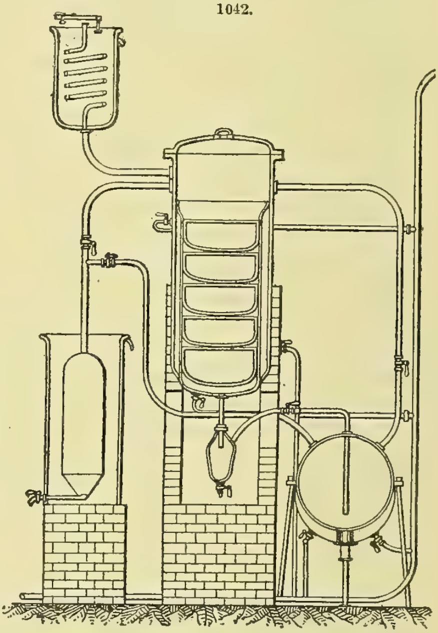
An apparatus recently constructed by Rigaud and Dussart is arranged so that dry steam enters directly among the matters to be distilled, and the temperature is always maintained at a high point. This is shown in Fig. 1042. It is claimed to yield a larger and superior product, and to prevent all chance of creating an empyreumatic odour, such as sometimes happens with other forms.

Distillation as a means of obtaining essential oils is worthy of every consideration. Generally it should be effected by steam; but there are cases (bitter almonds, &c.) where contact with water is necessary for the production of the oil, while in others, open fire and steam are equally applicable, though the latter is superior. The water employed must be perfectly pure and neutral, though in some cases (sassafras, cloves, cinnamon, &c.), common salt is added to raise the boiling-point. The receiver is always some form (there are many) of "Florentine receiver." In some instances (anise, &c.) where the distillation-products are solidifiable at a low temperature, the condenser-worm needs to be warmed instead of cooled.

1041.

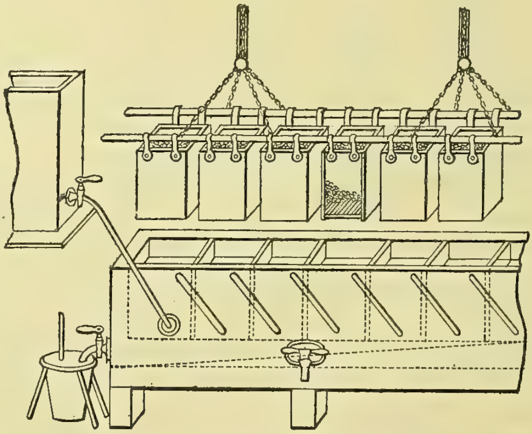


1042.



Maceration.—Some of the most delicately perfumed essential oils are spoilt by distillation; these are extracted by maceration in previously clarified solid fats or fixed oils. The grease to be perfumed is melted in a water-bath, and the flowers are thrown in, and allowed to remain for 24–48 hours, when they are withdrawn, freed from grease, and replaced by others, the operation lasting perhaps 15 days, and the product being numbered 6, 12, 18, 24, according to the amount of fragrance it has absorbed. Difficulties encountered in the conduct of the operation are the possible extraction of the colouring and other principles from the flowers, and the decomposition of the perfume and rancidification of the grease, by the repeated alternation of heat and cold. To obviate these drawbacks, Piver has introduced the saturator shown in Fig. 1043. This enables some 2100 lb. of grease, contained in 7 compartments, to be saturated in one day; the grease overflows by a spout leading from one compartment to another at the bottom, being kept in a liquid state by a water-bath meanwhile. Boxes of wire gauze carry the flowers, and advance in a contrary direction to the grease, each entering No. 7 and finally

1043.

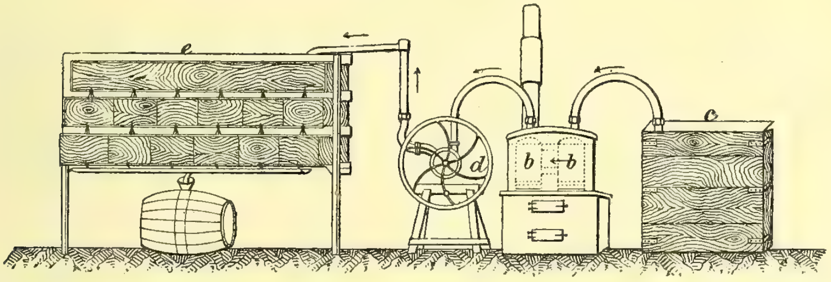


leaving No. 1 quite exhausted. This opposite passage brings the virgin oil into contact with the flowers which are nearly exhausted, while the already partially impregnated grease readily absorbs some of the excess of essential oil from the fresh flowers.

Refining, Clarifying, and Bleaching.—The various processes under this head may at first be broadly divided into "mechanical" and "chemical," although each, especially the latter, is capable of many subdivisions. They have for their object, firstly, the removal of all extraneous matters from the oil (using this term to include melted fats, as well as oils fluid at the ordinary temperature, since almost all these operations are conducted upon fluids), such as animal or vegetable fibre and tissue incidental to the modes of preparation (as in olive- and other seed-oils, badly-rendered tallow, &c.); secondly, of resinous substances dissolved in the oil, of which the refining of cotton-seed-oil is a notable example; thirdly, the removal of fraudulent admixtures, such as lime, glue, &c.; fourthly, the correction of rancidity; and fifthly, where the preceding operations do not sufficiently improve the colour of the oil, its bleaching by chemical processes. These will now be considered under their various heads, and it is obvious that much care and judgment are required in the selection of the particular method or combination of methods suitable to the refining of any given oil.

The first and most important method, to be employed either alone, or as a sequel to others, is that of simple but prolonged subsidence, on a large scale. Where necessary, the tanks employed may be heated by steam-coils or steam-jackets. These must be used with caution, however, since convection currents are set up, which interfere materially with the deposition of impurities. An obvious modification of this method is filtration, which may be effected in a very great variety of ways, either with or without the assistance of artificial pressure derived from (*a*) a "head" of the liquor to be filtered, (*b*) one of the many forms of filter-press in use, or (*c*) atmospheric pressure, by the production of a vacuum *under* the filter-bed (see p. 307). For example, olive-oil is mostly subjected to no process of purification, beyond what is attained by allowing it to deposit impurities, and repeatedly decanting. But for the best qualities, further purification is necessary, not only to secure limpidity, but a capacity for lengthened preservation, by eliminating the water, mucilage, and parenchymatous matters. Various devices are employed in different localities, one and all being filters. In France, the oil to be purified is received into perforated boxes carpeted with carded cotton (wadding); elsewhere, cotton tissue interposed between beds of granular and washed animal charcoal form the filter; also a bed of dry moss, on the 'Grouvelle et Jaunez' system; also layers of sand, gypsum and coke; also alternate beds of sand and vegetable charcoal, according to Denis de Montfort's plan; also carbonized schist and peat, by Cossus' method; also clay heated to 200° (? F.), as proposed by Wright; also by introducing China-clay and allowing to stand at a moderate temperature, then filtering through cotton, as adopted by A. Bizzarri. Perhaps the best mode is that of Pietro Isnardi, of Livornia, Tuscany, which received an award at the Vienna Exhibition. This apparatus, Fig. 1044, consists of a boiler full of water, serving as a water-bath for two turned-iron cylinders *b*, receiving the oil from the reservoir *c*, a suction- and force-pump *d*, and a filter *e*, containing perforated trays whose holes are filled with wadding. This apparatus enables the oil to be filtered without coming into contact with the air, and at an elevated temperature which can be regularly maintained. Coco-nut-oil is another example of purification by simple subsidence and filtration.

1044.



Where filtration fails to remove impurities, recourse may be had to the action of acids or alkalies upon them. There are several methods of applying mineral acids to the purification of oils. Thénard's process consists in gradually adding 1–2 per cent. of sulphuric acid to oil previously heated to 38° (100° F.), and mixing by constant agitation. When the action of the acid is complete, the oil, after 24 hours' rest, appears as a clear liquid, holding flocculent matter in suspension; a quantity of water heated to 60° (140° F.) equal to about $\frac{2}{3}$ of the oil is added, and the mixture is well agitated until it acquires a milky appearance. It is then allowed to settle for a few days, when the clarified oil rises to the surface, while the flocculent matter falls to the bottom with the acid liquid. The oil is then drawn off, and washed in another vessel by agitation with half its bulk of warm water; but it requires to be filtered to make it perfectly clear. This process is largely used for refining linseed-oil.

Cogan operates upon about 100 gal. of oil with about 10 lb. of sulphuric acid, previously diluted with an equal bulk of water. This mixture is added to the oil in three portions, the oil being well stirred for about an hour after each addition. It is then stirred for 2–3 hours to ensure perfect mixture. After being allowed to stand for 12 hours, it is transferred to a copper boiler with a perforated bottom, through which, steam enters and passes in a finely divided state through the oil, raising it to the temperature of 100° (212° F.). This is continued for 6–7 hours, and the oil is transferred to a cooler, shaped like an inverted cone, terminating in a short pipe, and provided with a stop-cock at the side, a little distance from the bottom. After standing till the liquids are separated, generally about 12 hours, the acid liquor is drawn off through the pipe at the bottom, and the clear oil by the stop-cock in the side of the cooler; all below this tap is generally turbid, and is clarified by subsidence, or mixed with the next portion of oil.

These acid processes are efficient when well conducted, but too much or too little acid may spoil the product, because, as most of them depend for their action upon the fact that strong sulphuric acid chars organic substances by the removal from them of the elements of water, it chars the fibre in the oil first, but if more acid than necessary for this be present, it attacks the oil itself, and oil thus stained by charring cannot be completely decolorized again.

On this account, perhaps, more general preference seems to be accorded to alkaline processes. Evrard's, which is chiefly applied to colza- and rape-oils, is as follows. The oil, drawn cold, or at very slight heat, is well crutched up with a weak lye of soda or potash, and allowed to settle. Two layers soon form—a neutral oil floating on an alkaline liquid, a mixed emulsion intervening. The alkaline liquid is drawn off, and replaced by slightly alkaline water, and the whole is left to settle. This is repeated a few times with clear water, till the liquid at the bottom of the settlers is only slightly milky. The oil is drawn off and filtered, and is superior to oil purified by sulphuric acid, being much less corrosive to metal. The turbid residual waters are treated with acid, and give a greasy product fit for soap-making. A much simpler alkaline method adopted in Italy for olive-oil is to add 400 *grm.* of ammonia, diluted with 800 *grm.* of water, to every 100 *kilo.* of oil, agitating thoroughly, allowing to stand for 3 days, and then decanting and filtering.

One of the most remarkable impurities in fats, arising from methods of preparation merely, is that of lime in bone-fat. This fat has the power of dissolving considerable quantities of lime-salts, especially phosphate and carbonate. No amount of subsidence or filtration will remove them, and their presence in a soap-copper is most objectionable. It is greatly to be desired, therefore, that English makers of this fat would follow the example of their American confrères, and boil their bone-grease, after removal from the extractors (p. 1449), with a weak solution of sulphuric acid, in lead-lined wooden tanks. This removes all the lime, in the form of sulphate, which deposits on the floor of the tank after due subsidence; it also removes the gelatine and extraneous water entangled in the bone-fat, which cause the crude grease to froth greatly when heated.

A good example of the removal of resinous substances from oils is afforded by the process adopted for refining and bleaching cotton-seed-oil, an industry which has enormously developed both in England and the United States, within the last 15 years. When freshly expressed from new seed, this oil is of a light-claret colour, which darkens by long keeping, in which case also, the oil becomes more viscid, probably from oxidation of some of its constituents. The colouring matter is almost entirely resin, which may be removed by agitation at about 60° (140° F.) with solution of carbonate of soda. It is found in practice, however, that a much better result is obtained by the use of a caustic alkali—solution of soda, potash, or, in some rare cases, milk of lime. The amount of alkali thus employed depends entirely upon the quality of the crude oil, and is best determined by a preliminary experiment upon a small scale. A solution of caustic soda at about 1·10 sp. gr. is a suitable strength. Agitation must be thorough, and may be effected by any convenient mechanical means. The process is a rapid one; if the saponaceous liquid does not readily separate from the oil, the addition of a little brine will cause it to do so. The operation is often divided into two or three stages, and occasionally the refined oil is bleached by one of the oxidation processes, such as by chloride of lime. After all the refining, it should be washed with warm water, allowed to settle, and decanted, or filtered at as low a temperature as possible, especially if an oil be desired that will remain fluid at a low temperature. This process will answer well for any resin-containing oil. The imperfect soap, after removal, is treated with enough mineral acid to remove all the soda, and the resulting mixture of resin, fatty acids, and neutral oil is distilled with superheated steam (see Candles) for the manufacture of fatty acids, the resin being left in the still as pitch. The chief seat of this industry in England is at Hull. In the United States, the quantity of resin is so small, that the "foots" from the cotton-seed-oil refineries are made into a curd soap (see Soap).

For the removal of fraudulent admixtures from commercial oils, no general rule can be given; but subsidence, filtration, and boiling with weak sulphuric acid, will generally effect the desired result. Special methods are best sought under the head of Detection and Analysis, pp. 1462–77.

Methods for correcting rancidity in oil are as follows:—(*a*) Agitation with 5 parts of good vinegar, repeating the operation several times. (*b*) Agitation (5–6 times) of 50 parts of oil with 80 parts of water at 30° (86° F.) holding 12 parts of common salt in solution. (*c*) To 100 *litres* of oil, are added 2 *kilo.* of calcined magnesia; the mixture is agitated 4 times daily for ½ hour each time for 6 days; the oil is then filtered; it must be quickly used, or it will become rancid again. (*d*) Agitation with a weak solution of caustic alkali, or a moderately strong one of an alkaline carbonate. (*e*) Prolonged agitation with water.

Most of the processes for refining and bleaching oils also deodorize them to a certain extent. As many of the odorant principles are more volatile than the oils, they may occasionally be removed by merely heating the oil in a closed vessel provided with an exit-pipe. For destroying the disagreeable smell of coco-nut-oil for soap-making, it is recommended to boil it in a wooden vessel by free steam on water containing 6 lb. sulphuric and 12 lb. hydrochloric acid to each ton of oil. Prolonged steaming will sometimes remove the unpleasant odour characteristic of oily distilled products.

Many plans of decolorizing oils are in vogue:—(*a*) Exposure to sunlight in large white glass bottles; the oil soon becomes colourless, but acquires an almost rancid flavour. (*b*) Agitation with 2 per cent. of a solution of permanganate of potash; bleaches effectually, but also leaves a bad flavour. (*c*) The oil is first agitated with water containing gum, and to the emulsion thus formed, is added coarsely crushed wood-charcoal; the whole is then slowly warmed to a degree not reaching 100° (212° F.), and when cold, the oil is dissolved out by ether or petroleum-spirit, and the latter is recovered by distillation; the result is good. (*d*) A process much recommended is to pass nitrous acid gas through the oil. (*e*) The oil (500 parts) is clarified by addition of 50 parts of China-clay and 50 of water. (*f*) In some cases, it is found advisable to use the coagulation of albumen in clarifying oils. The oil to be treated is mixed by agitation at the ordinary air-temperature with a weak solution of albumen in water. The whole is then gradually heated, most conveniently by steam, and when hot enough to coagulate the albumen, this latter collects in clots, enclosing particles of impurity; after the lapse of sufficient time, these clots subside, and the clarified oil is removed by decantation. The process is analogous to that of the refining of syrups by serum of blood.

Many oils are partially or completely decolorized by filtration through, or agitation with, freshly-burnt animal-charcoal or bone-black. The apparatus for filtering is similar to that employed in sugar-refineries (see Sugar), and consists essentially of tall wrought-iron cylinders filled with bone-black, and provided with a steam-jacket to control their temperature. When the charcoal ceases to decolorize, it should be treated with some solvent (bisulphide of carbon, or petroleum-spirit) to remove the oil, before it is revivified by calcination.

Most processes for the bleaching of oils depend upon the oxidization of the colouring matter by some suitable reagent, chiefly evolving nascent oxygen in some form. There are, however, instances known in which the colour is destroyed by a reducing agent, such as sulphurous acid, in an aqueous solution, as gas, or arising from the decomposition of an alkaline hyposulphite (e. g. that of soda) by a strong mineral acid. It may be laid down as a general rule that oils which have been burnt or charred by any previous process cannot be satisfactorily bleached. Experiment alone can determine the particular process best suited to any given oil, having regard to the purpose for which it is to be used. The utmost care is required in using any oxidation process for fats intended to be converted into soap, since if the fat be oxidized in any perceptible degree, as well as the colouring matter, (i. e. if too much of the bleaching reagent be used), the resulting soap will often be worse in colour than if the fat had not been bleached at all.

Palm-oil and tallow are the two chief fats bleached by the soap-maker. Both may be bleached by pumping air into them in finely divided streams, while they are kept at about 82°–93° (180°–200° F.). The colour of tallow may also be removed by boiling upon a solution of chloride of lime, or of chlorate of potash, to which a strong mineral acid has been added. No more potassic chlorate than 0·1 per cent. on the tallow should be employed.

Experiment has shown that the colour of palm-oil may be quite destroyed by heat. To effect this, the oil may be kept for some hours at about 127° (260° F.), or it may be put into a closed, horizontal, iron cylinder, and heated by a fire beneath up to about 240° (464° F.), at which temperature the colour is destroyed. This process gives rise to most offensive vapours, especially acrolein, and necessitates the conduct of operations in a closed vessel, with suitable means of condensing the vapours and rendering them innocuous, such as have been already alluded to under Floor-cloth (p. 1004), and elsewhere (pp. 1272–6, 1449).

Palm-oil may also be very suitably bleached by bichromate of potash and hydrochloric acid. The oil is made as free as possible from impurities, and, at about 49°–54° (120°–130° F.), is agitated with a strong solution of bichromate of potash, containing about 1 lb. of the salt to every 100 lb. of oil. To this, is added enough hydrochloric acid to form sesquichloride of chromium with all the chromium in the bichromate of potash, the quantity of liquid acid necessary of course varying with the amount of real acid contained in it. A slight excess of acid is rather an advantage than otherwise. The process occupies about an hour, after which, subsidence removes most of the chemicals, while subsequent agitation with hot water renders the oil quite pure enough for the soap-copper.

Detection and Analysis.—The ordinary solid fats and fixed oils (with the exception of butter and a few others) may be looked upon as mixed glycerides of oleic, stearic, and palmitic acids, in various proportions, the first preponderating in the oils, and the two last (especially stearine) in the fats. For ordinary purposes, there are therefore the following constituents to deal with:—(1) Moisture, especially in butter and palm-oil; (2) organic suspended matter, such as curd in butter; (3) mineral matters, such as salt in butter; (4) total fatty acids, in any ordinary oil or fat; (5) oleic, stearic, and palmitic acids, in any ordinary oil or fat; (6) soluble and insoluble fatty acids, only necessary in butter, and the few exceptional fats similarly constituted; (7) glycerine, from which to calculate the glyceryl in the fat; (8) possible presence of paraffin-wax and mineral oils.

A. ORDINARY EXAMINATION OF FATS. (1) *Estimation of Moisture in Fats.*—25 *grm.* of the fat are weighed into a carefully tared porcelain dish, which is then placed over a low gas-flame, and stirred with a thermometer, taking care that the temperature is maintained above 100° (212° F.), but not exceeding 110° (230° F.). This is continued until no more bubbles of vapour escape, indicating that all the moisture has been expelled; the whole is then allowed to cool. When cold, the thermometer is carefully drawn out, and any fat remaining attached to it is scraped off and returned. If, however, an instrument with a long narrow bulb be used, and it be carefully loosened by gently turning it round, usually no fat will adhere on withdrawing it. The dish plus the fat is then weighed, and the tare being deducted, the remainder is the dry fat in the 25 *grm.* taken, which, multiplied by 4, gives percentage of pure fat, and the difference between that and 100 represents the percentage of moisture.

(2) and (3) *Estimation of Organic and Mineral matters present as Impurities in Fats.*—This applies to the estimation of curd and salt in butter, and of fibrous and mineral impurities in oils and fats, and is thus conducted. The contents of the dish already used for moisture are melted, and the melted fat is poured off as far as possible without disturbing the sediment. Some petroleum-spirit, rectified at a temperature not exceeding 87° (188½° F.), is poured into the dish, and the whole is well stirred, and transferred to a previously weighed filter. By means of successive portions of petroleum, the whole of the contents of the dish are washed on to the filter, and all traces of fat are completely washed away from the other matters, which remain on the paper. The filter is then dried at 100° (212° F.), weighed, and the tare having been deducted, the remainder is organic matter plus mineral matter (or, in a butter, curd plus salt).

The filter and contents are then transferred to a previously weighed platinum crucible, and heated for some time to dull redness, till the ash becomes greyish-white. The crucible and ash are weighed, and the weight of the former being deducted, the difference is mineral matter (or, in a butter, salt). The mineral matter thus found is deducted from the former result, and the difference is the organic matter, and each multiplied by 4 gives the respective percentages.

(4) *Estimation of the total Fatty Acids in any ordinary Fat or Fixed Oil not containing Glycerides of Soluble Acids.*—This process, which is also applicable to the estimation of the total insoluble acids in a fat containing glycerides of soluble acids, divides itself into two heads, as follows:—

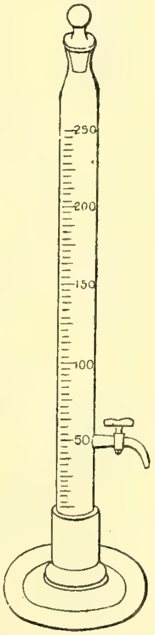
(*a*) Preparation of the sample.—If the sample be a perfectly clear and dry oil, it is at once ready for use; but if it be at all turbid, or if a solid fat, a portion must be placed in a tube, and kept in the water-oven below 100° (212° F.), until any moisture and heavy suspended impurities have settled to the bottom. A well-dried filter-paper is then placed in a funnel over a dry beaker, also in the water-oven, and the nearly clear upper portion of the melted fat is filtered, until a sufficient quantity is thus obtained fit for analysis.

(*β*) Process of analysis.—A perfectly clean and dry 5-oz. flask is accurately tared on the balance, and 5 *grm.* of the melted fat are carefully weighed into it. (It is not important exactly to a fraction, but as nearly 5 *grm.* as possible should be taken, and, in any case, the weight must be noted with great care.) To this, are then added about 30 *c.c.* of methylated spirit 60 o.p., and a fragment of caustic potash weighing about 2 *grm.*, and the flask is then placed in a basin of boiling water, until the whole of both fat and potash have dissolved, and the addition of a little water produces no permanent turbidity, which will be attained within 10 minutes, as a rule. The contents of the flask are then poured into a basin, and the flask is washed out with repeated quantities of boiling distilled water, until the contents of the basin measure about 250 *c.c.*, and no trace of soap remains in the flask. The basin is then placed over a low gas-flame, and evaporated till it ceases to give off spirituous vapours, a little boiling distilled water being added, if necessary, to prevent too great a loss by evaporation. The contents of the basin are then transferred to a 600-*c.c.* flask (1 pint size), the basin is washed with boiling water, and the washings are added to the flask. A slight excess of hydrochloric acid is then added, the whole is boiled, and shaken with a circular motion until a perfectly clear layer of fatty acids separates on the surface, and is set to cool. If the acids solidify on cooling to a good solid cake, well and good; but if not, a carefully weighed quantity of pure white wax must be added, and melted with the layer of fatty acids, so that, on cooling, they solidify firmly. This is always necessary in the case of oils, but not usually with solid fats. The mouth of the flask is then covered with a piece of ordinary cambric, held *in situ* by an indiarubber ring under the lip, so as to form a filter, and, the cake having been detached from the flask by a gentle motion, the watery liquid is poured off. Some boiling distilled water (about 200 *c.c.*) is then poured into the flask, and the whole is again boiled, well shaken, and cooled. The liquid below the cake is passed through the cambric as before, and this washing is repeated until the fluid collecting below the cake ceases to give a cloud with argentic nitrate. Care having been taken that, at the last pouring off, the cake has not been at all broken, the flask is inverted, and left to drain for the night with the cambric still attached. In the morning, the flask is placed in the water-oven till the cake has thoroughly melted, the cambric is removed, and the fat is then carefully poured into a dry and accurately tared platinum capsule, dried in the water-oven at 100° (212° F.), and weighed. The cambric is put into the flask, and the fat still adhering to both is washed out with small successive quantities of petroleum-spirit into a previously weighed small beaker. The petroleum is then evaporated off on the water-bath, the residual fat is weighed, and its weight is added to that of the main quantity already weighed in the capsule. The united weight then represents the total fatty acids in the quantity of fat taken, and is calculated to percentage by multiplying by 100, and dividing by the weight taken for analysis. It sometimes happens that an obstinate little globule of water forms below the melted acids in the weighing-capsule, and refuses to dry up; but this is easily removed by adding a little absolute alcohol, and again drying in the water-oven. The alcohol thus used carries off with it in volatilizing the little trace of moisture remaining.

(5) *Estimation of the Oleic, Stearic, and Palmitic Acids.*—To do this, advantage is taken of the solubility of oleate of lead in ether, so enabling its separation from the stearate or palmitate of the same metal. As formerly conducted, this was a tedious and not over accurate process; but by the apparatus and process devised by Dr. Muter, the estimation is rendered simple. Three cases present themselves, as follows:—

(*a*) For the Oleic Acid in non-drying Oils and Fats.—A small quantity (not more than 1·5 *grm.*) of the purified fat is saponified by alcoholic potash in a flask, washed into a basin with boiling distilled water, and the alcohol is removed by evaporation, all as described before in the estimation of the total fatty acids. The solution is kept boiling, and treated with acetic acid, drop by drop, until a decided *permanent* turbidity is produced; dilute solution of caustic potash is then added by drops, with *constant stirring*, until the liquid *just clears again.* The clear solution is then precipitated by plumbic acetate in slight excess, and stirred until the precipitated soap settles thoroughly. The supernatant liquor is poured off, and the soap is at once washed by boiling with a large volume of distilled water, and decanting. By this process, are obtained the perfectly neutral lead salts, containing:—Plumbic oleate ($Pb2C_{18}H_{33}O_2$), plumbic palmitate ($Pb2C_{16}H_{31}O_2$), and plumbic stearate ($Pb2C_{18}H_{35}O_2$). The first is readily soluble in ether; the two last are quite insoluble. The soap is scraped from the basin with a platinum spatula, and transferred to a flask of 100 *c.c.* capacity. The basin is rinsed into the flask with absolute ether, and then the flask is filled up with the same solvent, corked, shaken at intervals for some hours, and finally set to subside. The whole is then filtered through white blotting-paper, and the precipitate is washed with ether, till the washings cease to blacken with ammonium hydrosulphide. The filtrate and washings (which should not exceed 200 *c.c.*) contain the plumbic oleate, while the palmitate and stearate remain on the filter. Having thus got a solution of pure neutral oleate of lead in ether, it is transferred to a long tube of 250 *c.c.*, graduated from the bottom upwards, furnished with a well-ground stopper, and having a stopcock placed at 50 *c.c.* from the bottom (Fig. 1045). About 20 *c.c.* of a mixture of one part hydrochloric acid and two parts water are then added; the tube is stoppered, well shaken, and set to subside, when a clear solution of oleic acid remains, the plumbic chloride sinking to the bottom. When sufficiently settled, a fixed portion of the ethereous solution is run off through the stopcock into a tared platinum dish, evaporated at a gentle heat, then dried at 100° (212° F.), and the oleic acid is weighed and calculated to the whole bulk. To make sure, it is well to run off two different quantities, and weigh them, so checking one by the other.

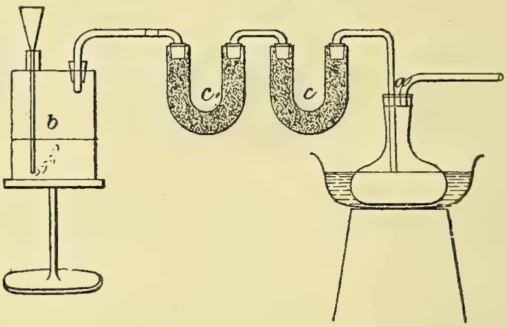
1045.



1046.

(β) For the Oleic Acid in drying Oils.—The process is conducted in a precisely similar manner up to the point where the whole has settled in the tube. A definite portion of the ethereous liquid is then run into a perfectly dry wide-mouthed flask of about 6 oz. capacity, carefully tared on the balance. The flask (Fig. 1047) is then fitted with a cork *a*, through which pass two tubes, one going down nearly to the surface of the liquid, and the other just passing through the cork. To the long tube, are attached two U-tubes *c*, filled with freshly-ignited chloride of calcium; to that again, is joined a gas-bottle *b*, in which a steady stream of hydrogen is generated from zinc and dilute sulphuric acid. When the air has been expelled from the flask by the stream of dry hydrogen, a basin is placed under it, and warm water is poured into the basin, so as to cause the ether to evaporate. When the ether is nearly gone, the water in the basin is kept boiling till the ether is entirely evaporated (i. e., till no more smell of ether is observable at the mouth of the exit-tube). The basin is then removed, and the flask is allowed to cool (still keeping up the stream of hydrogen); when cold, it is detached and weighed, and, the tare being deducted, the weight of oleic acid is calculated to percentage.

1047.



(γ) For the Stearic and Palmitic Acids.—The residue left on the filter, after extraction with ether, is carefully scraped off, and heated for some time (with constant stirring), which will liberate the acids, so that they will, on cooling, form a cake; this is washed, dried, and weighed, as described in section (4). The filter-paper is also to be burned in a weighed porcelain crucible, and the ash treated with a drop or two of sulphuric acid, and again ignited. After cooling, the crucible is weighed, and, the tare being deducted, leaves the equation—as 303 : 568 : : the weight of the residue; the answer, added to the weight of the cake already found, gives the total solid fatty acids (stearic and palmitic), which is then calculated to percentage. If it be desired to find the approximate proportion of each of these acids, the process is as follows. Several glass tubes are drawn out at one end to a long thin point, as in Fig. 1046 (natural size). The cake of mixed acids is then melted, and a little is sucked up into a pair of such tubes, until the drawn-out parts are entirely filled, and both are allowed to cool. They are then suspended side by side with a delicate thermometer, in a small beaker filled with water, taking care that the thermometer has a long narrow bulb placed exactly between the two tubes. Heat is now applied to the beaker, and at the moment that the fat in the thin tubes becomes transparent, the degree of heat is read off. The whole is allowed to cool gradually, and the temperature is again read at the moment of resolidification. By referring to the following tables, an approximate result is obtained.

TABLE OF THE MELTING- AND SOLIDIFYING-POINTS OF MIXTURES OF STEARIC AND PALMITIC ACIDS.

Stearic Acid, proportion by weight.	Palmitic Acid, proportion by weight.	Mixture melts at	Mixture resolidifies at
90	10	67·2° (153° F.)	62·5° (144½° F.)
80	20	65·3° (149½° F.)	60·3° (140½° F.)
70	30	62·9° (145¼° F.)	59·3° (138¾° F.)
60	40	60·3° (140½° F.)	56·5° (133¾° F.)
50	50	56·6° (133¾° F.)	55·0° (131° F.)
40	60	56·3° (133¼° F.)	54·5° (130° F.)
35	65	55·6° (130¼° F.)	54·3° (129¾° F.)
30	70	55·1° (131° F.)	54·0° (129¼° F.)

It should be mentioned that this table is by no means certain when the mixtures are in some other proportions. Thus, a mixture of 10 stearic and 90 palmitic will show a melting-point of 60·1° (140¼° F.), but its cooling-point will be about 54·5° (130° F.), instead of 56·5° (133¾° F.), so that even to get fair approximation, both the melting- and the resolidifying-points must be taken. Pure stearic acid melts at 69·2° (156½° F.).

(6) *Analysis of Fats containing Glycerides of both Soluble and Insoluble Fatty Acids.*—The most generally interesting fat in this series is butter, which has to be distinguished from the artificial butter manufactured from solid beef-suet, and known in commerce as "oleo-margarine" or "butterine"

(see p. 1362). Remarks will therefore be specially directed to this subject, merely pointing out that the same process would be available for coco-nut and palm-nut-oils, or any of the few other fats containing soluble acids. Suet, and the artificial butter manufactured from it, will yield on melting, settling, and filtering, a fat containing about 95·5 per cent. of insoluble fatty acids; but the fat of butter will be found to possess on an average very nearly the following composition:—Insoluble fatty acids (chiefly oleic and margaric), 88; soluble fatty acid (calculated as butyric), 6; total, 94. From an estimate of both the soluble and insoluble acids, it follows that deficiency of the former and excess of the latter gives a good basis for detecting adulteration. This may be done in two ways, viz., by specific gravity, and by analysis.

(α) Examination of Butter by "actual density."—The term "actual density" was applied by Dr. Muter to this method as meaning the weight of any given volume of butter at 37·8° (100° F.), divided by that of the same volume of distilled water at the same temperature, to distinguish it from ordinary sp. gr. compared with water at 15½° (60° F.). The actual density of pure butter ranges from 0·912 to 0·914, while that of butterine is 0·903–0·906. Consequently there is a difference on the lowest estimate of 0·006, and an approximate judgment can be made as follows:—All butter, 0·912 or over; ⅔ butter, 0·910; ½ butter, 0·909; ⅓ butter, 0·908; all butterine, 0·906 or under. It is, however, customary to pass as "good," butter having an actual density of anything over 0·911, because, by keeping, the density increases; but, to cause a fall below this point, it would require a degree of rancidity so great as to produce complete unfitness for either alimentary or analytical purposes. The process is carried out as follows:—The butter is first kept melted till all the impurities settle down, and the clear fat is filtered, as already directed in the estimation of "total fatty acids." A special sp. gr.-bottle is procured, of a pear shape, and having a thermometer fused through the stopper. The thermometer has a long narrow bulb, running right through the centre of the bottle, and its scale, which is from 15½ to 48·9° (60°–120° F.), is entirely above the stopper. This bottle is exactly counterpoised, and is then filled with recently boiled distilled water at 35° (95° F.). The stopper is inserted, and the whole is at once plunged up to the neck into a 12-oz. squat beaker, partially filled with distilled water at 39½° (103° F.), in which is placed a thermometer. As the temperature rises in the bottle, the water leaks out at the stopper, and in a few minutes (if the quantity of water in the beaker be properly regulated), a time arrives at which the two thermometers equalize themselves at 37·8° (100° F.). The joint between the stopper and the bottle is instantly wiped by a small piece of blotting-paper to absorb loose water, and the bottle is lifted out, wiped thoroughly dry, and weighed. This process having been repeated three times, the average weight is scratched on the bottle with a diamond, and it is then ready for use. The pure butter-fat, prepared as already described, is melted in the water-oven, and cooled to 35° (95° F.). It is then poured into the bottle till full, the stopper is inserted, and the whole is plunged into the beaker of water at 39½° (103° F.). The same operations are gone through as just directed for the water, and the weight so obtained is divided by that marked on the bottle. The contrivance of having a *rising* fat heated by a *falling* water until the two equalize is the perfection of accuracy, and moreover gives *an appreciable rest in the variation of temperature*, sufficient to enable the excess of fat which has leaked out to be removed exactly at the required point.

(β) Chemical analysis for the amounts of soluble and insoluble acids.—For this purpose, the following reagents are necessary:—

a. Semi-normal volumetric sulphuric acid, containing 49 *grm.* H_2SO_4 per *litre.* This is made by weighing out 50·6199 *grm.* pure oil of vitriol, sp. gr. 1·843, and diluting with distilled water to 1 *litre.* Each *c.c.* of this acid will represent 0·088 *grm.* of soluble butter-acids, calculated as butyric acid, or 0·09 of soluble butter-acids on the basis that they are 90 per cent. butyric and the rest chiefly caproic.

b. Volumetric normal solution of sodium hydrate, containing 40 *grm.* real NaHO per *litre*, and made by dissolving say 45 *grm.* of ordinary caustic soda in a *litre* of distilled water, then filling a burette with this solution, and running it into 100 *c.c.* of the volumetric sulphuric acid placed in a beaker, to which a few drops of alcoholic solution of phenol-phthallein have been added, until it produces a pink colour. The number of *c.c.* of the soda solution used having been noted, ten times that quantity is placed in a test mixer, and made up to 1 *litre* with distilled water. Each *c.c.* of this alkali will now represent 1 *c.c.* of the acid.

c. Volumetric normal solution of potassium hydrate in methylated spirit, made by dissolving 60 *grm.* of ordinary caustic potash in 1 *litre* of methylated spirit, checked, and made up with spirit, exactly as directed for the sodium hydrate solution. It is to be preserved in a well-stoppered bottle, and always checked again before use.

d. An ordinary solution of barium chloride.

The process is performed as follows:—5 *grm.* of melted and purified butter-fat (as directed under "total fatty acids") are weighed into a 5-oz. flask, 50 *c.c.* of the alcoholic potash (*c.*) are carefully added from a burette, and the whole is boiled on a water-bath for about 15 minutes, or until the addition of a little water produces no turbidity. This solution is washed into a long, narrow, graduated measure with successive quantities of distilled water, till the whole measures 300 *c.c.*, and it is then divided into two parts of 150 *c.c.* each. In part A, the insoluble acids are estimated; in part B, the soluble.

Part A is treated with solution of barium chloride, until no more precipitate forms; the precipitate is collected on a filter, and well washed with warm water. It is then transferred to a "Muter's oleine tube" (see Fig. 1045) having a wide mouth, by washing it in with distilled water, and allowed to settle. As much as possible of the water is drawn off by inclining the tube forward and running off the clear water at the stopcock; 20 *c.c.* of diluted hydrochloric acid (1 acid to 2 water) are added, together with 100 *c.c.* of pure ether; the stopper is introduced, the tube is well shaken, and then allowed to settle till the ethereous solution separates. The amount of the ethereous solution is noted, and a definite quantity (say one-half) is drawn off into a tared platinum capsule; the ether having been evaporated off, the residual acids are weighed, all as already directed for the estimation of oleic acid in non-drying oils. The weight, first doubled (if half the ethereous liquid has been used), and then multiplied by 40, gives the percentage of the insoluble acids in the butter-fat. The amount of adulteration is best calculated on this result by the following formula, in which, P is the weight per cent. of insoluble acids found, and x the percentage of adulteration.

$$\frac{(P - 88) \times 100}{7 \cdot 5} = x.$$

Looking, however, to the fact that the insoluble acids in butter increase by age and rancidity, no article should be positively condemned which shows less than 90 per cent. of insoluble fatty acids. Once the adulteration is thus rendered certain, its percentage should be calculated, as above, on the ordinary standard of good butter.

If preferred, the insoluble acids in butter may be estimated by the process already detailed for total fatty acids in ordinary oils and fats, in section (4).

Part B is diluted with another 100 *c.c.* of water, placed in a flask, brought under a burette containing the volumetric sulphuric acid (*a*), and 50 *c.c.* are run in. The flask is then attached to an upright condenser, boiled until the insoluble acids separate in a clear oily layer, and then allowed to cool. The cake is detached, and the fluid is run off through a filter, made as directed in section (4), by fixing a piece of cambric over the mouth of the flask. Another 100 *c.c.* of boiling water is then added to the cake, and the whole is again boiled under the upright condenser; when cooled, the liquid is passed through the same filter. This operation is repeated, and the united filtrates are brought under a burette containing the volumetric sodium hydrate (*b*), and, a few drops of alcoholic solution of phenol-phthallein having been added, the solution is run in. When a pink colour has been produced, the number of *c.c.* used is noted, and this number, multiplied firstly by 0·09 and secondly by 40, gives the percentage of soluble fatty acids in the butter-fat.

(7) *Estimation of the Glycerine formed by Saponification.*—This is not generally necessary, except for scientific purposes, and it is customary to deduct the percentage of total fatty acids found from 100, and consider the difference as glyceryl. Up till the beginning of this year (1881), no ready process for the estimation of glycerine had been proposed; but since then, Dr. Muter has published the preliminary notice of a process which is likely to give good results. The author takes advantage of the power of glycerine in arresting the precipitation of cupric hydrate from cupric sulphate by potassium hydrate. He takes a definite quantity of the solution of glycerine in one of the oleine tubes already described (Fig. 1045), and to it, he adds an excess of potassium hydrate, and drops in a solution of cupric sulphate with constant shaking, until a permanent precipitate is produced. The whole is then made up to a definite bulk, and, when settled, a portion of the blue liquid is run off through the stopcock; the amount of dissolved copper is estimated by neutralizing with nitric acid, then adding excess of ammonium hydrate, and running in a volumetric solution of potassium cyanide till decolorized. By doing this on a solution of glycerine of known strength, the value of the cyanide in glycerine is ascertained. Those interested will find details in the *Analyst* for March 1881.

(8) *Testing a Solid Fat for Paraffin-wax and Mineral Oils.*—The mixture of fats with solid mineral hydrocarbons has become of late years quite an acknowledged custom. Therefore, any fat should always be submitted to the "actual density" process described for butter, on p. 1465. Ordinary fats have an "actual density" at 38° (100° F.) rarely below 0·9032, while solid paraffin-wax treated in the same way shows nothing above 0·8810. If, therefore, an apparent fat shows less than the latter figure, it is probably all mineral; but if somewhere between the two, it is most likely a mixture, and must be treated in the same manner as hereinafter described for the detection and estimation of heavy mineral oil in ordinary fatty oils. The test for paraffin-wax in oils is, as hereafter shown, so simple, that it is advisable always to apply it, unless the fat shows a density so high as to positively preclude its presence.

B. Identification of Oils in Mixtures.—The next subject claiming attention is the identification and testing of oils, especially when mixed, a point of the greatest difficulty, and one which eminently requires experience. It does not, like the subject just finished, rest on a definite chemical basis; and although many processes have been from time to time advocated, none has really stood the test of repetition by other hands. The peculiarity of oils is that one analyst may have methods which may and do give fair results in his own hands, but which, repeated by others without his special experience, become not only inaccurate, but positively misleading. It would be quite possible to make an apparently valuable *résumé* of the subject, by giving all the processes above referred to, and still to leave the reader really no nearer his desired object than at the commencement. The aim of the present article, however, is to avoid this beaten track, and to omit everything but the few definite points which, intelligently followed up and backed by practice, may lead to the fairest deduction possible in the present state of science. The first essential in setting about the study of oils is the possession of a set of really genuine standard samples; this is very difficult to procure, as the oil-trade is so permeated by the principle of admixture, that the refiners have too often good reason to shun any attempts to render its detection more easy. To test the real state of matters in this respect, the writer once applied to seven leading houses to assist him with standards; only one came forward in response. Nothing, however, can be done without standards of, at least, the following kinds:—

Marine Animal Oils.

Fish (cod)
Whale
Seal
Sperm
Cod-liver.

Terrestrial Animal Oils.

Lard
Neats'-foot
Horse-bone
Tallow (oleic acid).

Mineral Oils.

Ordinary paraffin
Heavy lubricating.

Drying Vegetable Oils.

Linseed
Hempseed
Nut.

Partially Drying Vegetable Oils.

Cotton
Castor.

Manufactured Oil.

Rosin.

Non-drying Vegetable Oils.

Olive
Almond
Rape
Colza (refined rape)
Ground-nut
Coco-nut.

Many other oils exist, but the foregoing represent such as are commonly met with in commerce. If, however, the reactions of others should be desired in any special case, it will be easy to follow out the methods hereinafter given, and fix one's own reactions, if not found in the present article, which must necessarily be limited.

The following reagents and special articles are required:—(1) Pure carbon bisulphide; (2) petroleum-spirit, rectified under 88° (190° F.); (3) alcoholic caustic soda, made by dissolving 115 *grm.* of sodium hydrate in 1 *litre* of redistilled methylated spirit; (4) sodium bicarbonate, pure; (5) silver sand, well washed, dried, and ignited; (6) barium polysulphide, made by dissolving barium oxide in boiling distilled water, cooling, pouring off the mother-liquor from the crystals, boiling it with excess of sulphur, and filtering; (7) syrupy zinc chloride, made by saturating hydrochloric acid with pure zinc oxide, and evaporating till the liquid assumes the consistence of golden syrup; (8) sulphuric acid, sp. gr. 1·843, which has been shaken up with a little mercury occasionally during some hours; (9) stannic chloride, the fuming perchloride of tin of commerce; (10) syrupy phosphoric acid, ordinary phosphoric acid evaporated to a sp. gr. of 1·72; (11) mercuric nitrate, made by dissolving mercury to saturation in cold nitric acid, and then boiling for ten minutes with as much more nitric acid; (12) absolute sulphuric acid, the strongest acid, which has been recently heated for some time to 316° (600° F.), then boiled, and quickly secured in an air-tight vessel; (13) amylic alcohol, sp. gr. 0·818; (14) a sp. gr.-bottle, fitted with a thermometer stopper from 60° to 120° F.; (15) a long delicate thermometer, graduated in single degrees from 0° to 149° (32°–300° F.); (16) some long test-glasses of $1\frac{1}{2}$ in. diameter, capable of holding 150 *c.c.*, and made to stand heat; (17) some dropping-tubes, delivering slowly drops of water weighing $\frac{9}{10}$ gr.; (18) some white porcelain capsules, semicircular in form, and 2 in. diameter, without spouts; (19) some small glass rods, 3 in. long.

(1) *Examination for Mineral and Rosin Oils.*—

(*a*) Warm the oil, and smell it. If it gives off the odour of paraffin, it contains ordinary illuminating mineral oil. In this case, carefully counterpoise a watch-glass, and having weighed on to it about 1 *grm.* of the oil, keep it in an air bath heated to 110° (230° F.) until the weight is constant; note the loss of weight, and calculate to percentage of paraffin-oil.

(*b*) Place 10 *grm.* of the oil in a basin with 20 *c.c.* of the alcoholic caustic soda (No. 3 reagent), heat to boiling on a water-bath, and evaporate nearly to dryness. Then add 75 *c.c.* of distilled water, and boil for half-an-hour. Observe the nature of the resulting mass or liquid, and note one or other of the following cases.

Case 1. An emulsion only is formed. Probably there is only mineral or rosin oil. Add water, and warm, when, if a clear oil separates, mineral oil is present, but if brown, then rosin-oil may be present. Now draw off the aqueous liquid from beneath, and make it acid with sulphuric acid. If no precipitate forms, the oil was all mineral; but if a precipitate be produced, collecting on warming in brown viscous drops, then the presence of rosin-oil is confirmed.

Case 2. A semi-pasty mass is obtained. Probably it is an ordinary fatty oil mixed with mineral or rosin-oil. Add water, and warm, when the mineral oil, if present, will float to the surface. Now draw off the aqueous liquid, and shake it up with amylic alcohol; if the alcohol separates in a brown layer, rosin-oil was present. Once more draw off the aqueous liquid, acidulate with hydrochloric acid, and warm, when the separation of oleic acid, with its characteristic odour of fat, will show the presence of the fatty oil. This would also apply in the case of testing a solid fat for paraffin-wax.

Case 3. A perfectly pasty soap is formed, which dissolves in warm water without any separation of oil. The sample is an ordinary fatty oil, containing possibly (though not likely) a little rosin-oil. Shake up with amylic alcohol, when, if no brown colour be produced in the alcohol, no rosin-oil is present. Once more draw off the aqueous liquid, add an excess of sodium chloride (which will precipitate the fatty soap) and filter. If the oil be a pure fatty one, the warmed filtrate will only give a slight turbidity on acidulating with hydrochloric acid, and will smell of fat; but if the solution give a copious precipitate, and, when heated, has a resinous odour, the oil contains rosin. If, on setting free the fatty acids from the soap with hydrochloric acid, and cooling to 15½° (60° F.), they partly solidify, animal oil, such as lard or neats'-foot, may be suspected, although certain vegetable oils (such as cotton-seed), especially when crude, give tolerably solid acids. (The fatty acids of coco-nut-oil, and palm-nut-oil, when liberated and heated, smell of volatile fatty acids, just like butter, and the insoluble portion is very low).

Having thus got a fair preliminary idea of the constitution of the sample, it may be confirmed by taking the "actual density" at 38° (100° F.), as already directed for butter (p. 1465). If the "actual density" of the article be under 0·900, it is all mineral oil; if between 0·900 and 0·960, it may be either all fatty oil, or a complex mixture; while if over 0·960, it is all rosin-oil.

(2) *Estimation of a Mixture of heavy Lubricating Mineral Oil and Rosin-oil.*—There is no known method of chemically separating these, and so an approximation must be made from the "actual density." Mineral oils for lubricating have an "actual density" not exceeding 0·880, while rosin-oil is generally about 1·000; therefore the following table may be taken as approximate, which, however, is only good in the ensured absence of fatty oils.

All mineral	0·880	60 per cent. rosin	0·952
10 per cent. rosin	0·892	70 „ „	0·964
20 „ „	0·904	80 „ „	0·976
30 „ „	0·916	90 „ „	0·988
40 „ „	0·928	All rosin	1·000
50 „ „	0·940		

The reader is warned that this is only approximate, as there are samples of rosin-oil as low in "actual density" as 0·9800.

(3) *Estimation of Mineral Oil in Fatty Oils.*—20 *grm.* of the sample are saponified with 35 *c.c.* of the alcoholic caustic soda (reagent No. 3) in a deep basin on the water-bath; 20 *c.c.* of redistilled methylated spirit, or sufficient to perfectly dissolve the soap, are added. The whole being still kept boiling on the bath, 9 *grm.* of sodium bicarbonate are added little by little, well stirring after each addition, so that all the excess of alkali may become carbonate; 50 *grm.* of sand (No. 5 reagent) are stirred in so as to thoroughly mix the whole, and the evaporation is continued until a perfectly dry residue is obtained. This residue is now packed into a stoppered percolator, and covered with petroleum-spirit (No. 2 reagent), and the whole is allowed to macerate for an hour; the stopper is then opened, and percolation is commenced into a 40-oz. flask, until the spirit has run off. More petroleum is then added, and percolation is continued until a few drops of the liquid evaporated on a watch-glass cease to leave any residue. This takes in all a considerable quantity of petroleum, so that sometimes the whole percolate measures nearly 1 *litre.* The flask containing the petroleum is then attached to a condenser, and the bulk of the petroleum is reduced by distillation to something under 100 *c.c.* The residue is transferred to an "olein tube" (see p. 1463), and the flask is rinsed with warm petroleum, so that the contents of the tube measure, say 150 *c.c.* A platinum capsule is carefully tared, and a measured small aliquot part of the fluid in the tube is run into it, from the stopcock, and evaporated to dryness at

a temperature not exceeding 104½° (220° F.). The residue is weighed, and calculated to the whole bulk of the fluid; that result, multiplied by 5, gives the percentage of mineral oil. As a rule, the tendency of the process is to come out about 0·5 per cent. too high, so that any fraction of a per cent. under or over 0·5 may be disregarded, i.e., if 20·4 per cent., to simply call it 20 per cent., but if 20·8 per cent, then report 20·5 per cent. To check the weighing, it is desirable to run off more than one small aliquot part, and evaporate and weigh. This process is equally applicable to the detection of paraffin-wax in solid fats.

(4) *Estimation of Rosin in Fatty Oils.*—To perform this with anything like accuracy, requires a tedious separation, in which the oil is saponified with alcoholic caustic soda, and the soap is dissolved in water. Dilute sulphuric acid is dropped in until the liquid becomes permanently turbid, and then dilute sodium hydrate is added drop by drop till it just clears again. The whole is then mixed with sand, and evaporated to perfect dryness, to ensure which it is necessary to moisten the apparently dry residue with absolute alcohol, and again dry. The residue is packed into a stoppered percolator, and extracted with a mixture of 5 parts by volume of absolute ether and 1 of absolute alcohol. The solvent is distilled off, and the residue is dissolved in water, and warmed with a slight excess of sulphuric acid, when the rosin separates in viscous drops, which are collected and weighed. These drops still contain a little oleic acid, and, if perfect accuracy be desired, must be dissolved in alcohol, and the solution polarized, which, however, is a process requiring special training and appliances, and is therefore beyond the scope of the present article. Indeed the estimation of a very small percentage of rosin in boiled linseed-oil, for example, is a problem requiring the highest skill and practice, and if under 2 per cent., it is, in the present state of science, practically impossible.

(5) *Estimation of Tallow-oil (free Oleic Acid) in an Ordinary Oil.*—This point is an important one because oils containing free oleic acid are unsuitable for lubricants. 50 *grm.* of the oil and 100 *c.c.* of alcohol are placed in a flask with a few drops of tincture of turmeric, or an alcoholic solution of phenol-phthallein, and well shaken.

A normal volumetric solution of sodium hydrate (40 *grm.* per *litre*, each *c.c.* of which represents 0·282 oleic acid) is dropped in until a red colour is produced, and the whole is again shaken. This is repeated until the red is permanent; the number of *c.c.* of sodium hydrate used are read off, and multiplied by 0·282, and then by 2, which gives the percentage of free oleic acid.

Before this process is undertaken, a little of the oil should be shaken up with alcohol of 60 o.p., and the alcoholic solution, when clear, mixed with a few drops of alcoholic solution of acetate of lead. If no precipitate be produced, no free fatty acid is present.

(6) *Mutual Detection of the various Fatty Oils.*—Having discussed all the cases of mixtures with other oils, we now come to the actual identification of the various fatty oils themselves.

The first step is to train the nose to distinguish between certain main groups. To do this, take some oil in a small flat porcelain basin, warm it up to about 142° (300° F.), and observe the smell. Then, as soon as sufficiently cool, rub some into the palm of the hand, and again smell. A little practice will thus permit the easy detection and distinction between (1) marine animal oil, (2) terrestrial animal oil, (3) vegetable oil. The odours of these three classes are entirely *sui generis*, and it is safe to pronounce on the main question by this test. The marine oils have all the repulsive fishy odour in various degree, the sperm requiring most practice; the other animal oils have all the peculiar sourish smell of cooking animal fat, soon learned by experience; the vegetable oils, on the other hand, have a more or less sweetish odour, and practice will even enable most of them to be named.

Case 1. The oil is evidently a marine animal oil. Take the "actual density" at 38° (100° F.) (see p. 1465), and compare with the following table:—

	Highest extreme.	Lowest extreme.	As commonly met with.
Cod (fish)	0·9220	0·9114	0·9176
Cod (liver)	0·9180	0·9173	0·9179
Seal	0·9195	0·9136	0·9150
Whale	0·9066	0·9056	0·9060
Sperm	0·8963	0·8672	0·8724

To confirm this, take 10 drops of the oil in a porcelain capsule (No. 18, p. 1467), add (from a dropping-tube) 5 drops of barium polysulphide (reagent No. 6), and stir rapidly with a small rod, when sperm-oil will become golden-yellow, and remain so, while the others will be very pale after a few strokes of the rod and setting aside for 5 minutes. Now take a similar quantity of oil, add 5 drops of zinc chloride (reagent No. 7), and stir, when whale and cod-liver will not change, or will only become pale-violet, while seal and cod-fish will be yellow or orange, the former exhibiting brown spots, the latter not. Next, to another similar portion of oil, add 5 drops of sulphuric acid (reagent No. 8), when cod-liver will alone give a violet, the others going brown at once. Then, to another similar portion of oil, add 5 drops stannic chloride (reagent No. 9), when whale-oil will only turn orange-yellow, seal and fish becoming red-brown, and cod-liver violet and then red. Lastly, to another similar portion of oil, add 5 drops mercuric nitrate (reagent No. 11), and after stirring, add a drop or two of sulphuric acid, when seal-oil will effervesce, and give off red fumes.

Case 2. The oil is apparently of terrestrial animal origin. Take, as before, the "actual density," when a pure oil of this class will never vary more than from 0·9050 to 0·9082. Tallow-oil (free oleic acid) is put out of the question in the preliminary examination by alcoholic acetate of lead, and so there can be only:—

	Highest extreme.	Lowest extreme.	As commonly met with.
Lard	0·9082	0·9076	0·9078
Neats'-foot	0·9079	0·9052	0·9070

All the members of this division bleach to a very pale-yellow with barium polysulphide, while lard-oil becomes perfectly white, and gives off a slight smell of sulphuretted hydrogen. They give scarcely any colour with zinc chloride, and become dark reddish-brown with sulphuric acid. A persistent yellow with the polysulphide, a green or brown with zinc chloride, and a greenish tint or too light a brown with sulphuric acid, would indicate impurities of vegetable oil. The only ones which, however, could be mixed without raising the density would be rape, nut, and olive, while sperm would lower the density. Characters of special varieties of neats'-foot-oil will be found in the general tables (pp. 1472–5).

Case 3. The oil is apparently vegetable in origin. Take, as before, the "actual density":—

	Highest extreme.	Lowest extreme.	As ordinarily met with.
Olive	0·9079	0·9052	0·9070
Rape	0·9077	0·9060	0·9067
Almond	0·9109	0·8980	0·9056
Refined rape (colza)	0·9065	0·9053	0·9067
Ground-nut	0·9092	0·9073	0·9085
Nut	0·9090	0·9080	0·9084
Refined cotton (salad)	0·9140	0·9130	0·9136
Poppy	0·9155	0·9150	0·9154
Coco-nut	very variable, from 0·9103 to 0·9152		
Cotton (brown)	0·9197 (an exceptional sample)	0·9170	0·9176
Hempseed	0·9195	0·9190	0·9193
Linseed	0·9300	0·9232 (an exceptional sample)	0·9252
Boiled linseed	0·9440	0.9320	0·9380
Castor	0·9576	0·9550	0·9558

Now proceed to use the reagents in the capsules, putting 5 drops of the reagent (from the dropping-tubes) into 10 drops of oil, and stirring; note the following effects:—

1. Barium polysulphide goes very pale-yellow only with inferior olive, ground-nut, and castor; and greenish with hempseed and very bad olive. The density throws out castor and hempseed, and only ground-nut and inferior olive are left. Try zinc chloride, when olive gives a green, and ground-nut a yellow. Confirm ground-nut by saponifying, and throwing up the fatty acids with hydrochloric acid. Then dry them, and dissolve in 4 parts of alcohol of 85°. To this, add an excess of rectified spirit, when, if ground-nut-oil be present, white flakes of arachidic acid will deposit; these may be collected, dried, and weighed. By treating pure ground-nut-oil side by side, the percentage of it in a mixture may be deduced.

2. Zinc chloride gives a green or greenish-yellow with olive, rape, colza, almond, linseed, and cotton. Olive and colza are green, linseed yellow or greenish-yellow, rape yellow, cotton (when heated) brownish, while almond is milky with a greenish tinge. The density excludes definitely linseed and cotton; it remains to distinguish between the others. Try stannic chloride, when, if a

green be produced, it is rape or colza; olive and almond respectively give faint-yellow or no colour. If it be not rape or colza try phosphoric acid, which will decolorize almond-oil, and turn olive-oil green. To distinguish between linseed and cotton, if required, try sulphuric acid; linseed goes orange-yellow, while cotton goes deep reddish-brown.

3. Sulphuric acid. There only now remain to be considered poppy- and nut-oils. The former becomes dark-brownish by agitation with sulphuric acid, while the latter only goes orange-yellow.

Having thus ascertained, by the density and reactions, the purity of the oil, and named it, the next case is that of a mixed vegetable oil; it is here that the experience comes into play. The most valuable help [in addition to the "actual density," and the full tables of reactions of all the oils hereafter appended (see pp. 1472–5), as devised by Chateau, and somewhat modified by the present writer, who uses by preference a different reagent for the first group], consists in the following process, originally proposed by Maumené. 50 *grm.* of the oil are carefully weighed into a tube, the temperature is taken with the long delicate thermometer (No. 15), 10 *c.c.* of absolute sulphuric acid (reagent No. 12) are added from a pipette, and the whole is rapidly stirred with the thermometer until it ceases to rise, and the number of degrees through which it has gone up are registered. According to the originator, we should get the following results, in about 2 minutes, the results being constant if the acid be used of the same strength, and the surrounding temperature be kept equable:—

Olive gives a rise of	108° F.	Gingelly gives a rise of ..	154° F.
Castor ,, ...	116° F.	Poppy ,, ..	187·5° F.
Neats'-foot ,, ...	122·7° F.	Hemp ,, ..	208° F.
Bitter almond ,, ...	125° F.	Nut ,, ..	214° F.
Sweet almond ,, ...	126·5° F.	Train (ray liver) ,, ..	215·5° F.
Rape ,, ...	134° F.	,, (cod) ,, ..	215·5° F.
Beech-nut ,, ...	149° F.	Linseed ,, ..	217° F.
Ground-nut ,, ...	152° F.		

The phenomenon is easily defined and observed, and gives distinctions much more characteristic than those yielded by any of the former methods. The phenomena remain the same if two oils are mixed together. Thus two measures of olive-oil and one of poppy-oil should show:—

$$\begin{array}{llll}
\text{2 vol. olive-oil} & = 2 \times 108 & = & 216 \\
\text{1 vol. poppy-oil} & = 1 \times 187{\cdot}5 & = & 187{\cdot}5 \\
\hline
\text{3 vols. mixture,} & & & 403{\cdot}5^{\circ}\text{ F.} \\
\text{Or 1 vol.} & & = & 134{\cdot}5^{\circ}\text{ F.}
\end{array}$$

and the experiment really gives this result, as has been ascertained by repeated trials with this and other mixtures.

In practice, the present writer did not succeed well with this process, for although he occasionally came up to these figures, yet the use of so hygroscopic an article as absolute sulphuric acid is always uncertain; he is, therefore, now in the habit of using the following process:—

Preserve some pure sulphuric acid, of sp. gr. 1·845, in a well-stoppered and capped bottle, never leaving the stopper out for more than the moment required to extract some of the contents. Get a tin vessel about 5 in. deep and capable of holding at least 2 qt. of water. Have some glass tubes on feet, capable of standing heat, about 1½ in. in diameter, and holding about 7 oz. of liquid. Have the acid in a bottle 6 in. high, with a thermometer inside. Counterbalance the tube, and weigh in accurately 50 *grm.* of the oil. Raise the water in the tin vessel to 28° (82° F.), immerse both the sulphuric acid bottle and the tube in the water, and place the long thermometer inside the latter. As soon as both the acid and the oil are at a temperature of 27° (80° F.), draw out 10 *c.c.* of the former with a pipette, and let it flow gradually (at the rate of 1 *c.c.* every 5 seconds) into the latter without touching the sides, stirring all the time with the thermometer. After all the acid is in, continue to stir rapidly for exactly ½ minute, keeping the tube in the water with one hand and stirring with the other, and then move the thermometer more slowly, noting the exact degree at which it ceases to rise. From that, deduct 80, and the difference is the amount of rise. Treated in this way, and using a definite hydrated acid, the rise of temperature is not quite so great, but it is (at least in the writer's hands) much more constant. With him, olive-oil gives a rise of 106° F., rape-oil of 131° F., and so on, very nearly in proportion to the original figures. It cannot, however, be too strongly impressed that every one using this process must fix his own standards *according to his own method of working*, and that a pure standard oil should always be done *in precisely the same manner* immediately before the suspected article. For this reason, the writer prefers not to give his own tables of results, as no two persons, unless actually working side by side, will ever get absolutely identical figures.

General Tables of the Full Reactions of all the Usual Oils, according to Chateau, but somewhat modified by the Writer.

Group I.—To 10 drops of the oil in a white porcelain capsule, add 5 drops of barium polysulphide (reagent No. 6), stir with a glass rod, and note whether the golden-yellow colour remains after 20 strokes of the rod, or whether it bleaches, and becomes very pale-yellow or white, as under :—

Case 1.—The Golden Colour remains with :—		Case 2.—The Colour fades to Canary-yellow, or alters with :—	
Vegetable.	Animal.	Vegetable.	Animal.
Linseed. Poppy. Nut. Almond. Olive. Rape. Colza. Cotton. *Gingelly.* *Gold of pleasure.*	Sperm. *Neats'-foot* (*very rarely*).	Castor. *Poppy* (*Indian*). Hempseed (G. to G. Y.). Olive (*inferior*). Ground-nut. *Beech-nut.* Coco-nut.	Neats'-foot. Horse-bone. Lard (bleaches with slight H_2S). Fish. Cod-liver. Seal (B. Y.). Whale. Tallow (much H_2S).

Notes.—G., green; G. Y., greenish-yellow; B. Y., bright-yellow; H_2S, gives off sulphuretted hydrogen. Unusual oils in italics.

Group II.—To 10 drops of the oil in a porcelain capsule, add 5 drops zinc chloride (reagent No. 7), stir, and observe whether the oil is scarcely affected, or develops distinct colour :—

White, or scarcely affected.		Distinct Yellow to Brown.		Green or Blue Shades.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy. Nut. Almond (*hot-pressed*). *Gingelly.* Coco-nut.	Neats'-foot. Lard. Horse-bone. Sperm. Whale (*sometimes pale-violet tinge*). Cod-liver (cold).	Linseed. *English* (Y.) Rape (Y.) Ground-nut (Y.) Castor (R. Y.) Beech (F. R.) Cotton (B.)	Whale (Y. B.) Fish (O. Y.) Seal (R. B.)	Linseed (*foreign* B. G.) Olive (G.) Colza (G.) *Gold of pleasure* (G. pale). Almond (milky with G. tinge).	Cod-liver (*hot* G.)

Notes.—Y., yellow; R. Y., rose-yellow; F. R., flesh-rose; O. Y., orange-yellow; B., brown; Y. B., yellow-brown; R. B. red-brown; G., green; B., G., bluish-green.

Group III.—To 10 drops of the oil in a capsule, add 5 drops sulphuric acid (reagent No. 8), and observe firstly without agitation and secondly with; 3 cases occur: (1) some shade of brown, (2) some shade of yellow, and (3) a greenish tint:—

Some Shade of Brown.		Some Shade of Yellow.		Greenish or Green Veins.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Linseed *foreign* (R. B.). Nut (R. B.). Ground-nut (R. B.). Beech *agitated* (B. R.). Cotton (B. R.). Coco-nut (R. B.).	Lard (R. B.). Neats'-foot (*agitated* R. B. with Gy. S.). Horse-bone *agitated* (R. B.). Fish (S. B.). Seal (R. B.). Sperm (R. B.). Whale (R. B.). Cod-liver (V. to D. B.).	Poppy (D. Y.). Castor (D. Y.). Olive (R. Y. to B.). *Gingelly.* Almond (P. Y., O. Y. and G. Y.).	Neats'-foot (rarely) (O. Y. with Gy. S.).	Hempseed (G. to R. B.). Linseed (G. B.). *English.* Colza (G. S.). Rape (B. G.). *Gold of pleasure.*	None.

Notes.—R. B., red-brown; B. R., brownish-red; Gy. S., grey spots; S. B., Sienna-brown; D. Y., dark-yellow; O. Y., orange-yellow; G., green; G. B., greenish-brown; G. S., green spots; V., violet.

Group IV.—To 10 drops of the oil in a capsule, add 5 drops stannic chloride (reagent No. 9), stir, and observe firstly the immediate colour, and secondly the colour of the thickened or solidified mass :—

Case 1.—The coloration takes place instantaneously.

Yellow, Faint Yellow (F. Y.), Golden Yellow, no colour.		Brownish Red, Distinct Brown (D. B.), Reddish Yellow (R. Y.), Brownish Yellow (B. Y.).		Green, Greenish-bluish, Green, Greenish Blue.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy (French). Castor. Olive. *Gingelly.* (F. Y.). Sweet almond (no colour).	Neats'-foot (Paris). Lard (O. Y.).	Linseed all qualities (B. Y.). White Poppy (India) (R. Y.). Nut (R. Y.). Olive (huile d'enfer). (R. Y.). Pea-nut (distinct B.). *Gold of pleasure.* Beech (R. Y.). Cotton-seed O. Y. (?) Coco-nut (D.B.)	Neats'-foot (R. Y.). Lard (R. Y.). Horse-bone (R. Y.). Whale (O. Y.). Sperm (purplish R. B.). Seal. Fish (deep R. B.).	Linseed (English) green veins. Ditto (N. Europe) (bluish G.). Ditto (Bayonne) (bluish G.). Ditto (India) bluish G.). Hempseed. Rape-seed. Colza.	Cod-liver, passing from violet-blue to dragon's-blood. Ray, same.

Case 2.—The colour of the thickened or solidified mass.

Yellow, Faint Yellow (F. Y.), Bright Yellow (B. Y.), Straw Yellow.		Brown, Distinct Brownish Red (D. B. R.), Orange Yellow, (O. Y.), Reddish Yellow (R. Y.).		Green, Greenish, Dirty Green, Dark Green.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy (French). White do. (India). Castor (faint). Olive (refined). B. Y. *Gingelly.* Sweet Almond (Canary Y.). *Gold of pleasure* (Faint Y.).	Sheep-foot (Faint Rosy Y.).	Linseed (D. B. R.). Olive (Ordinary) (O. Y.). Colza. Pea-nut (B. R.). Beech (distinct R. Y.). Cotton (Y B.).	Neats'-foot (O. Y.). Horse-bone O. Y.). Whale (clear mahogany). Sperm (O. Y.).	Hempseed (Dark green). Olive, *inferior* (dirty-green). Rape-seed (dirty green).	None.

Group V.—To 10 drops of the oil on a capsule, add 5 drops phosphoric acid (reagent No. 10), stir and observe ; then heat, and again observe :—

Case 1.—Colours when cold.

Very little Effect.		Yellow to Orange.		Greenish to Bluish.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy. Nut. Castor. Almond. Rape (?). *Gold of pleasure* (?). Coco-nut.	Neats'-foot. Lard.	Linseed, *Foreign* (S. Y.). Ground-nut (S. Y.). Cotton (G. Y.). *Gingelly* (O.V.).	Horse-bone (O. Y.). Whale (O. Y.). Sperm (S. Y.). Seal (B. R.). Fish (R. Y.). Cod-liver (R. Y.).	Linseed, *English.* Hempseed (D. G.). Olive. Colza. Rape. *Gold of pleasure.*	None.

Case 2.—Colours on heating.

Colourless.		Yellow to Brownish-yellow.		Colour of the Froth on the Surface.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable	Animal.
Poppy. Olive (sometimes). Coco-nut (sometimes faint yellow).	Lard (sometimes very faint yellow.	Linseed (B. Y.). Poppy (B. Y.). Hempseed (R. Y.). Nut (B. Y.). Castor (B. Y.). Olive (R. Y.). Almond (B. Y.). Rape (B. Y.). Colza (B. Y.). Beech (B. Y.). Cotton (B. Y.). *Gingelly* (B.Y.). *Gold of pleasure* (B. Y.). Ground-nut (G. Y.).	Neats'-foot (B. Y.). Horse-bone (G. Y.) Sperm (B. Y.).	Gingelly (greenish). Hempseed (greenish). Olive .. .. Ground-nut *Gold of pleasure* .. Cotton .. } Grey. Linseed .. Castor .. Rape .. .. Colza .. .. Beech .. } Blackish.	Whale (greenish). Cod-liver (greenish). Sperm (grey). Neats'-foot (blackish). Seal (blackish). Fish (blackish).

Deep Browns.	
Vegetable.	Animal.
	Seal. Fish. Whale. Cod-liver.

Group VI.—To 10 drops of the oil on a capsule, add 5 drops mercuric nitrate (reagent No. 11), and observe the effect. Then add 2 or 3 drops of sulphuric acid, and observe the colour of the liquid which covers the precipitate:—

Case 1.—Colours given by the Salt alone.

White or Grey Emulsion, or No Coloration.		Yellow, Faint Yellow, Gold Yellow (G. Y.), Canary Yellow, Orange Yellow (O. Y.), Straw Yellow (S. Y.).		Greens—Greenish, Sea Green (S. G.), Bluish Green.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy, French. White (slightly yellowish). White Poppy (ditto). Nut (no coloration). Castor (white). Sweet Almond (greyish white). *Gingelly* (white). Beech (no coloration.) Coco-nut (flesh-colour).	Neats'-foot, Paris. Lard. Sperm (no colour).	Linseed (S. Y.). Olive, refuse (G. Y.). Rape (S. Y.). Pea-nut (faint Y.). *Gold of pleasure* (S. Y.) Gingelly (O.Y.). Cotton (faint Y.).	Neats'-foot (R. Y.). Horse-bone (O. Y.). Whale (faint Y.). Seal (reddish Y.). Fish (G. Y.). Cod (S. Y.). Ray (faint Y.).	Linseed, English. Hempseed (greenish after agitation). Olive (greenish Y.). Colza. Rape (S. G.). Gold of pleasure (faint G.).	None.

CASE 2.—Colours given by Sulphuric Acid added after the action of the Salt of Mercury. Appearance of the Liquor covering the Precipitate.

Greys—Fleshy Grey, Brownish Grey (B. G.), Rose, Greenish Grey (G. G.).		Yellows—Reddish Yellow (R. Y.), Orange Yellow.		Browns—Raw Sienna (R. S.), Reddish Brown (R. B.), Bright and Dark Chocolate.		Disengagement of Vapours of Nitrogen Compounds. Sudden Effervescence.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Hempseed (G. G. by agitation). Colza (dirty flesh colour then fleshy grey). Rape (B. G.).		Linseed, N. Europe (dirty Y. finally). Ditto, Bayonne (R. Y.). Ditto, India (dirty Y.). Ditto, English (deep Y.). White Poppy (R. Y.). Castor (canary Y. and Gold Y. at first). Olive, ordinary (R. Y.). *Gingelly* (green veins, then O. Y.)	Neats'-foot, Buenos Ayres (R. Y. at first). Horse-bones (dirty B. Y. at first).	Linseed, N. Europe (sepia R. B., then dirty Y.). Ditto, Bayonne (ditto). Ditto, India (R. B.). Poppy, French (dark B.). Nut (light B., dark B., blackish B.). Castor (dark B.). Hempseed (dark R. B. without agitation). Coco-nut (almost black). Olive, superfine (R. S. greyish). Olive, inferior (R. B.). Sweet Almond (light chocolate). Colza (brownish rose then light B.). Pea-nut (chocolate). *Gold of pleasure* (R. B. then chocolate). Beech (light R. B.). Cotton (light chocolate).	Neats'-foot, Paris (chocolate B.). Lard (ditto). Ditto, Buenos Ayres (R. B. and chocolate). Horse-bone (B. R. and chocolate). Tallow (light chocolate B.). Whale (dark chocolate B.). Sperm (light B. and black). Seal (br. bl.). Fish (ditto). Cod-liver (dark B.). Ray-liver (sepia).	Linseed, N. Ditto, Bayonne. Nut. Castor. The other drying oils do not effervesce like the above.	Tallow. Seal.

In entering upon the subject, it was stated to be essentially one requiring experience; as a fitting conclusion, and a practical illustration of how experience is to be applied, three examples may be given of analyses of mixtures which have recently come before the present writer.

I. *A Sample of Lubricating-oil.*—Very pale-yellow in colour, and smelling of paraffin-oil; 0·5 *grm.* heated at 110° (230° F.) till constant lost 0·1 *grm.* = volatile paraffin 20 per cent. A larger portion heated till it ceased to lose weight, then saponified, and tested, gave no separation of mineral oil. The colour proved that there was no rosin-oil, and the liquid when acidulated threw up fatty acids which, on cooling, partly solidified: *ergo* suspected lard or neats'-foot. The remainder on the watch-glass, after volatilizing the paraffin, had, while hot, the faint odour of lard-oil, and, treated with barium polysulphide, became almost colourless, and smelt slightly of sulphuretted hydrogen. A large quantity of the oil heated in a flat dish at 110° (230° F.) for some hours, and cooled to 38° (100° F.), had an "actual density" of 0·9077. Zinc chloride showed absence of olive-oil, therefore the report was:—Paraffin-oil, 20 per cent.; lard-oil, 80 per cent.

II. *A Sample intended to be sold as Salad-oil.*—Colour yellow with a faint greenish tint. Heated, it smelt of fine olive-oil, but slightly more rancid. Tests proved no mineral oil, and colour forbade rosin-oil. Actual density, 0·9092. Barium polysulphide, colour remained golden. Zinc chloride, green at first, but developed a decided pale-brown. Sulphuric acid, no green tinge, but a pale reddish-brown. The tests show that it is not colza; and some saponified, and the fatty acids dissolved in 4 parts alcohol, give no precipitate on diluting, therefore no ground-nut. The brown tinge with the zinc chloride could not have been produced by poppy, so that it is probably olive mixed with refined cotton. By density it would show about:—Olive-oil, 66 per cent.; cotton-oil, 33 per cent., if this conclusion be right. Next tried a standard sample of olive, and one of refined cotton, by the sulphuric acid method, and then tried the sample, when the comparative elevations in temperature showed 35 per cent. of cotton. Taking, therefore, a common-sense view of the matter, the oil was considered to be $\frac{2}{3}$ olive and $\frac{1}{3}$ cotton.

III. *A Sample of* "*American Marrow.*"—Too fluid for genuine marrow, and of a decidedly yellow tinge. Heated, smelt distinctly of dripping, but also had a slight smell of salad-oil. Tried barium polysulphide, when the colour paled, but still remained a little. Tried zinc chloride; no green, therefore not olive or refined rape, but became slightly tinged with brown. Saponified a portion, and proved absence of ground-nut and coco-nut (the latter by getting off no volatile fatty acids). Sulphuric acid gave deep red-brown. "Actual density," 0·9093. Tried a mixture of half refined cotton-oil and half beef-marrow: "actual density," 0·9095, and gave similar appearances with reagents. Took insoluble fatty acids of original, and found 94·9; all marrow gave 95·5; refined cotton gave 94·2. Therefore concluded it to be a mixture of genuine dripping or marrow with refined cotton-oil in equal proportions. J. M.

Additional Tests.—Another, and entirely different, method of recognising the purity of the fatty oils, but which is not applicable to mineral oils, depends upon observations of the melting-points of their fatty acids. By comparison with standard samples, and mixtures of known composition, this method will often give very reliable results, especially in conjunction with some of the tests previously described. It is also frequently very desirable to determine the "actual density" of the fatty acid, since so many fatty oils occur in commerce in a state of partial rancidity, that the density of the oil itself is not unfrequently affected thereby. If, however, the whole be converted into fatty acids, more constant and reliable results are obtained.

As an example of the application of the melting-point test, the familiar case of mixtures of olive-oil and cotton-seed-oil may be taken. The fatty-acids of refined cotton-seed-oil melt at 36° (97° F.), while those of pure olive-oil are about 30° F. lower, varying between 15½° and 21° (60°–70° F.), according to whether the oil comes from the first or last portions expressed. The inference from this is obvious.

In applying this test, it is of the *utmost* importance to ensure complete saponification of the oil, and it is very desirable to precipitate the soap from its solution in water by the addition of sodium chloride, and to dissolve the soap so precipitated in a fresh portion of water before decomposing it with mineral acid. Since there are so many ways of determining melting-points, which give different results, it is undesirable to quote actual figures here, or to do more than point out the method, and the importance of each operator keeping to one mode of working, and one system of recording his observations. Dalican's method, described on p. 1477, is the one usually adopted for determining melting- and solidifying- points.

A test for the presence of coco-nut- or palm-kernel- oils, in presence of any other vegetable or animal fatty oils, depends upon the quantity of salt required to separate or precipitate their soaps from solution in a given quantity of water. It may be thus applied:—To 10 *grm.* of the pure fatty acid, is added aqueous solution of caustic soda equal to 1·25 *grm.* soda (100%), in a beaker of 100–150 *c.c.* capacity, previously tared. The whole is then boiled, and water is added until the contents of the beaker weigh 50 *grm.* at 100° (212° F.). At this point, a saturated solution of sodium chloride is run into the beaker from a burette, and the whole is stirred and boiled over a gas-flame. It will be found that while only about 8–10 *c.c.* of the solution are required with ordinary oils, coco-nut-oil will require more than 50 *c.c.*, and mixtures of the two will take proportionate amounts to separate the soap. By keeping the solution just boiling, constantly stirring, and adding the sodium chloride gradually, the exact moment of precipitation of the soap may easily be observed.

For the detection and estimation of rosin in admixture with fats and fatty oils, the determination of the sp. gr. of the fatty acids will be found a very valuable guide. The greater the proportion of rosin, the higher is the sp. gr. Since, however, some of these fatty-acid mixtures are solid at 38° (100° F.), it is desirable to adopt a higher temperature, say 60° (140° F.), as a standard at which to perform the operation. As in every other case, unknown samples presented for examination must be compared with samples of known composition.

Another process, applicable to this same problem, as well as to similar ones, consists in making an "ultimate organic analysis" of the mixture, and determining by direct combustion the proportions of carbon and hydrogen in the sample, and of oxygen by "difference." Such an operation, however, can only be conducted by a skilled chemist, and cannot be described here.

It cannot be too clearly impressed upon the would-be acquirer of information on this subject, that, in the present state of chemical knowledge, there are no decided and definite tests for each kind of oil, as there are for each kind of mineral substance, and that, in arriving at a conclusion as to the composition of any oil or mixture of oils, the analyst can only be guided by what may not inaptly be described as "circumstantial evidence," several tests indicating a balance of probabilities in one direction.

In Dalican's work, quoted in the Bibliography of this article, minute instructions are given for testing the value of tallow, oils, &c., for candle-making and soap-boiling. It is stated that this method has been adopted as a standard by the tallow-melters, brokers, and candle-manufacturers of Paris, and it is claimed for it that it gives absolutely concordant and reliable results. The following is a summary of the process.

In an enamelled basin of at least 1 *litre* capacity, 50 *grm.* of the tallow (or oil) is heated till it begins to give off vapour [about 200° (392° F.)]. While this is heating, a mixture is made of 40 *c.c.* of pure caustic soda solution at 36° B. (1·324 sp. gr.), and 30 *c.c.* of alcohol 40° Cartier or 95°–96° Gay-Lussac (sp. gr. 0·815). This mixture is added gradually to the hot tallow, the whole being well stirred, until a solid mass is formed; 1 *litre* water is added, and the whole is boiled for 45 minutes. The soap solution is then decomposed by the addition of 60 *c.c.* of sulphuric acid at 25° B. (sp. gr 1·205), and the whole is boiled until the fatty acids are perfectly limpid, and free from clots.

To perform the "titration," which consists in a very careful determination of the melting-point, a glass tube, 10–12 *c.* long and 1½–2 *c.* wide, is filled two-thirds full with the fatty acids melted at as low a temperature as possible, and the tube is suspended in a flask by a perforated cork. The bulb of a delicate thermometer, whose stem is divided into fifths of a degree C., is placed in the centre of the mass of fatty acids, the thermometer being suspended for convenience of manipulation and observation. When the fatty acids begin to crystallize, a rotary movement thrice to the right and thrice to the left, is given to the thermometer. During this operation, the thermometer falls slightly and then *rises again to a point at which it remains stationary for at least two minutes.* This is the degree which is accepted as the "titre" of the tallow, and is sometimes called the melting-point, but is really the point of solidification, of the fatty acids.

From the titration so obtained, the per-centages of stearic and oleic acid in the original tallow may be deduced from the following table, constructed synthetically by Dalican, from commercially pure stearic acid, and oleic acid perfectly freed from stearic, margaric, and other hard fatty acids. In the table, 1 per cent. is allowed for loss by water and impurities, and 4 per cent. for loss by glycerine, contained in the original tallow.

Degrees C.	Percentage of		Degrees C.	Percentage of	
	Stearic acid.	Oleic acid.		Stearic acid.	Oleic acid.
40·0°	35·15	59·85	45·5°	52·25	42·75
40·5°	36·10	58·90	46·0°	53·20	41·80
41·0°	38·00	57·00	46·5°	55·10	39·90
41·5°	38·95	56·05	47·0°	57·95	37·05
42·0°	39·90	54·10	47·5°	58·90	36·10
42·5°	42·75	52·25	48·0°	61·75	33·25
43·0°	43·70	51·30	48·5°	66·50	28·50
43·5°	44·65	50·35	49·0°	71·25	23·75
44·0°	47·50	47·50	49·5°	72·20	22·80
44·5°	49·40	45·60	50·0°	75·05	19·95
45·0°	51·30	43·70			

N.B.—The range of this table is between 104° and 122° F.

It is scarcely necessary to add that, if the original fat be accurately weighed, the operations carefully conducted, and the fatty acids [freed from water by exposure to at least 120° (248° F.)] be then weighed, it will be seen at once whether the original tallow contained any undue impurity or fraudulent admixture. 50 *grm.* pure tallow should give 47·5 *grm.* fatty acids.

For various other commercial tests, Dalican's book may be consulted with advantage.

A special test for linseed-oil has been described under Floorcloth (pp. 1002–3). The reader may also consult the article on Soap.

Illuminating Values.—Attempts to employ mineral oils for the production of illuminating-gas have resulted in many practical methods being devised, and beyond the application of an atmosphere of one of the petroleum-products in some forms of electric lamp, the lighter oil or "spirit" (see Paraffin) is largely used for carburetting air both in "sponge" lamps for domestic purposes, and on a more extensive scale in petroleum-producing centres, such as Pennsylvania, Rangoon, and Honolulu. Fatty oils are devoted to illuminating purposes by burning them in their liquid state in lamps provided with wicks.

The results of numerous experiments made on the illuminating-qualities of fatty oils in France are recorded in the annexed table:—

(See also Photometry.)

Name of Oil.	Locality of Production.	Duration of Combustion in a		Mean intensity for a consumption of 40 grm. and 8 hours' duration, in a lamp with	
		Night-lamp.	Lamp with 1 wick.	1 wick of 0·021 m. dia.	2 wicks of 0·039 m. dia.
Colza	N. France	36 hours	29 hours	1·04 burner	1·14 burner
Colza (fine) ..	India	40 ,,	26 ,,	0·95 ,,	1·06 ,,
Colza (trade) ..	,, ...	4 ,,	11 ,,	0·39 ,,	0·83 ,,
Ground-nut ..	Senegal	39 ,,	35 ,,	1·05 ,,	1·04 ,,
Olive	Port Maurice ..	40 ,,	23 ,,	1·07 ,,	0·89 ,,
Sperm	N. America	27 ,,	29 ,,	1·05 ,,	0·01 ,,
Gold of pleasure	French Flanders ..	38 ,,	20 ,,	0·77 ,,	0·94 ,,
Wild rape	Black Sea	28 ,,	23 ,,	0·82 ,,	0·84 ,,
Linseed	Brittany	18 ,,	14 ,,	0·87 ,,	...
Whale	N. America	15 ,,	18 ,,	0·86 ,,	1·05 ,,
Gingelly	Syria	14 ,,	26 ,,	0·73 ,,	0·85 ,,
Coco-nut	Cochin China ..	55 ,,	41 ,,	1·06 ,,	1·18 ,,

Other points which have to be taken into consideration are the density, the co-efficient of expansion, and the congealing- and liquefying-temperatures of the oils. On the whole, the most suitable fatty oils for illuminating, stated in their order of merit, are colza, coco-nut, ground-nut, olive, sperm, and whale.

Petroleum and shale-oils, as compared with fatty oils, possess three advantages—cheapness, greater light for the same consumption, and lower flame and less useless divergence in small apparatus; but they are more liable to smoke when the supply of air is not properly regulated, and their manipulation requires greater care. They give an intensity of about one carcel burner for 30 grm. consumed per hour.

The comparative cost of a single light, and intensity of the luminary produced at the focus of the optical apparatus, by colza-oil and mineral oil, is thus estimated by J. N. Douglass, in his experience of lighthouse illumination, on the Trinity House System:—

	First cost.	Labour.	Annual Maintenance.	Total light per annum.	Cost of light per hour.	Cost of light per candle.
					d.	*d.*
Colza-oil	£7400	2 men	£793 15 0	1,782,504 candles	43·2	0·107
Mineral oil	£7400	2 men	£693 6 6	1,782,504 ,,	37·7	0·093

Heating Values.—Reference has been made to the utilization of creosote-oils (obtained by the distillation of coal tar) as fuel, in the article on Coal-tar Products (see p. 649). The application of bone-oil to heating purposes is described on p. 1450. All other oils, except mineral oils, possess too great a value in other ways to be economically used as fuel on anything like a commercial scale.

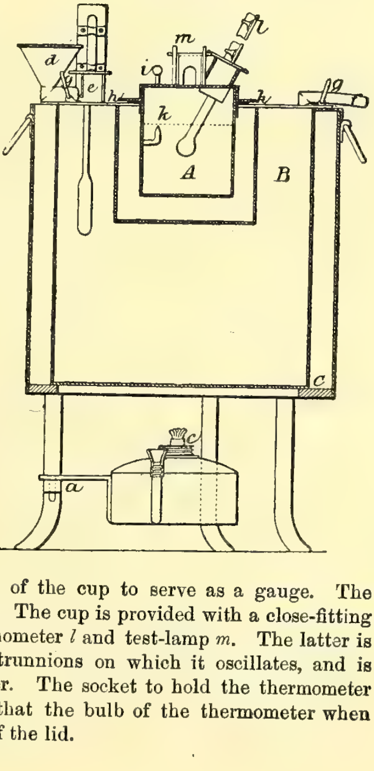
Of late years, great strides have been made in the direction of utilizing mineral oils, especially petroleum, as a source of heat for the generation of steam. Owen Ross deduces from a great number of analyses of petroleums that the calorific power in the lighter oils amounts to 27,000–28,000 heat units, and that 1 lb. of such fuel will suffice, when the gases are completely utilized, to evaporate 27–28 lb. of water, or nearly 4 times the effect ordinarily obtained from coal. The complete utilization of the gases is essential to secure this result, which necessitates the supply of air being slightly in excess of what is actually required for complete theoretical combustion of the hydrocarbon. It is estimated that the vapour from 1 gal. of petroleum-spirit of 0·655 sp. gr., and represented by the formula $C_{11}H_{26}$ (or 1607 lb. of carbon and 633 lb. of hydrogen in 1 ton of the spirit), will saturate nearly 263 cub. ft. of air; but it is considered inadvisable in practice to exceed such a proportion as will produce a gas burning without any deposition of carbon, so that 1 gal. of petroleum-spirit may be employed to carburet 700 cub. ft. of air. The result arrived at is the burning of all the carbon contained in the fuel to the state of carbonic acid, and all the hydrogen to water, avoiding smoke, soot, and other effects of incomplete combustion, and realizing almost the whole calorific power of the fuel. In the case of very high temperatures, petroleum fuel has a still greater advantage. It has been shown that in ordinary high-temperature furnaces using coal, the loss of heat amounts to $\frac{18}{20}$ of the total generated; this is largely due to the high temperature at which the combustion-products enter the chimney, but also to the great quantity of the products of combustion over which the caloric derived from the coal has to be distributed. This latter is reduced to little more than half in the case of petroleum-spirit. An additional advantage of great importance in most industries is the absence of sulphur from the fuel. It also permits the fire to be regulated with facility, and is especially useful when the pressure of steam is only required occasionally. The advantages of petroleum as a fuel are somewhat detracted from by the inconstant volatility of its constituents, and the danger of storing large quantities. Its range of utility will probably be confined to the neighbourhoods of its production; in England, it can hardly compete with coal in price, though much superior to it for very many purposes.

As to the best means of burning petroleum vapour, or, in other words, how best to effect the carburetting of the air and the combustion of the carburetted air, there is some difference of opinion; probably various plans will be found to suit various ends. Siemens' regenerative furnace and Eames' (American) furnace are well spoken of for employing the fuel in smelting operations. For steam purposes, perfect success has attended the adoption of the simple plan of conveying petroleum (or petroleum residues) by one pipe and steam by another to the mouth of the furnace, and blowing the petroleum into the furnace in a spray by means of the jet of steam.

Lubricating Values.—An efficient lubricator must exhibit the following characteristics:—(1) Sufficient "body" to keep the surfaces between which it is interposed from coming into contact; (2) the greatest fluidity consistent with (1); (3) a minimum co-efficient of friction; (4) a maximum capacity for receiving and distributing heat; (5) freedom from tendency to "gum" or oxidize; (6) absence of acid and other properties injurious to the materials in contact with it; (7) high vaporization- and decomposition-temperatures, and low solidification-temperature; (8) special adaptation to the conditions of use; (9) freedom from all foreign matters. The modern methods of testing the lubricating qualities of oils are directed to a discovery of the following points:—(1) Their identification and adulteration; (2) density; (3) viscosity; (4) "gumming"; (5) decomposition-, vaporization-, and ignition-temperatures; (6) acidity; (7) co-efficient of friction. The 1st and 2nd stages are described under Detection and Analysis, p. 1462. The viscosity and gumming tendency may be simultaneously detected by noting the time required by a drop to traverse a known distance on an inclined plane. A nine days' trial gave the following result:—Common sperm-oil, 5 ft. 8 in. on the 9th day; olive-oil, 1 ft. 9½ in. on the 9th day; rape-oil, 1 ft. 7¾ in. on the 8th day; best sperm-oil, 4 ft. 6⅓ in. on the 7th day; linseed-oil, 1 ft. 6¼ in. on the 7th day; lard-oil, 11¾ in. on the 5th day. The day given is in each case that on which the oil ceased to travel. There are several ways of applying the plane test. A very simple and general test of fluidity is to dip blotting-paper in the oil, and hold it up to drain: symmetrical drops indicate good fluidity; a spreading tendency, viscosity. Retention of the oil on the paper for some hours at 93⅓° (200° F.), or for some days at ordinary temperatures, will show the rate of gumming.

Fire-testing is specially applicable to mineral oils. There are several forms of tester, as Tagliabue's, Millspaugh's, Abel's, Saybolt's, Parrish's, Salleron-Urbain's, Sintenis', Bernstein's, and Bailey's. The apparatus consists essentially of a receptacle for the oil to be tested, a water-bath surrounding the receptacle, a lamp for heating the water-bath, a thermometer to indicate the temperatures, an outlet for the vapour generated from the oil, and a means of reaching the oil itself.

1048.



The form of tester recognized in this country under the Petroleum Act, 1879, is shown in Fig. 1048. The oil-cup A consists of a cylindrical vessel of 2 in. diameter and $2\frac{2}{10}$ in. internal height, with an outward projecting rim *h* $\frac{5}{10}$ in. wide, ⅜ in. from the top, and 1⅞ in. from the bottom of the cup. It is made of gun-metal or brass tinned inside. A bracket *k*, consisting of a short stout piece of wire bent upwards and terminating in a point, is fixed to the inside of the cup to serve as a gauge. The distance of the point from the bottom of the cup is 1½ in. The cup is provided with a close-fitting overlapping cover made of brass, which carries the thermometer *l* and test-lamp *m*. The latter is suspended from two supports at the side by means of trunnions on which it oscillates, and is provided with a spout, whose mouth is $\frac{1}{16}$ in. in diameter. The socket to hold the thermometer is fixed at such an angle, and its length is so adjusted, that the bulb of the thermometer when inserted to its full depth shall be 1½ in. below the centre of the lid.

The cover is provided with three square holes, one in the centre, $\frac{5}{10}$ in. by $\frac{4}{10}$ in., and two smaller ones, $\frac{3}{10}$ in. by $\frac{2}{10}$ in., close to the sides and opposite each other. These three holes may be closed and uncovered by means of a slide moving in grooves, and having perforations corresponding to those on the lid. In moving the slide so as to uncover the holes, the oscillating lamp is caught by a pin fixed in the slide, and tilted in such a way as to bring the end of the spout just below the surface of the lid. Upon the slide being pushed back so as to cover the holes, the lamp returns to its original position. Upon the cover, in front of and in line with the mouth of the lamp, is fixed a white bead *i*, the dimensions of which represent the size of the test-flame to be used.

The bath or heated vessel B consists of two flat-bottomed copper cylinders, an inner one of 3 in. diameter and 2½ in. height, and an outer one of 5½ in. diameter and 5¾ in. height; they are soldered to a circular copper plate C, perforated in the centre, which forms the top of the bath, in such a manner as to enclose the space between the two cylinders, but leaving access to the inner cylinder. The top of the bath projects both outwards and inwards about ⅜ in.; that is, its diameter is about $\frac{6}{8}$ in. greater than that of the body of the bath, while the diameter of the circular opening in the centre is about the same amount less than that of the inner copper cylinder. To the inner projection of the top, is fastened, by six small screws, a flat ring of ebonite, the screws being sunk below the surface of the ebonite, to avoid metallic contact between the bath and the oil-cup. The exact distance between the sides and bottom of the bath and of the oil-lamp is ½ in. A split socket similar to that on the cover of the oil-cup, but set at a right angle, allows a thermometer *e* to be inserted into the space between the two cylinders. The bath is further provided with a funnel *d*, an overflow pipe *f*, and two loop handles *g*.

The bath rests upon a cast-iron tripod stand, to the ring of which, is attached a copper cylinder or jacket, flanged at the top, and of such dimensions that the bath, while firmly resting on the iron ring, just touches with its projecting top the inward-turned flange. The diameter of this outer jacket is 6½ in. One of the three legs of the stand serves as support for the spirit-lamp attached to it by means of a small swing-bracket *a*. The distance of the wick-holder *c* from the bottom of the bath is 1 in.

Two thermometers go with the apparatus, one for ascertaining the temperature of the bath, the other for determining the flashing-point. The former has a long bulb and a space at the top. Its range is from about 32° to 88° (90°–190° F.) It is furnished with a metallic collar, fitting the socket, and the part of the tube below the scale should have a length of about 3½ in. measured from the lower end of the scale to the end of the bulb. The thermometer for ascertaining the temperature of the oil is similarly fitted with collar and ivory scale; it has a round bulb, a space at the top, and ranges from about 13° to 66° (55°–150° F.); it measures from end of ivory back to bulb 2¼ in.

The test is applied in the following manner:—The apparatus is placed where it is not exposed to draughts. The water-bath is filled by pouring water into the funnel *d* until it begins to flow out at the spout of the vessel. The temperature of the water at the commencement of the test is to be 54½° (130° F.), attained in the first instance either by mixing hot and cold water in the bath, or in a vessel from which the bath is filled, until the thermometer which is provided for testing the temperature of the water gives the proper indication; or by heating the water with the spirit-lamp (which is attached to the stand of the apparatus) until the required temperature is indicated.

When a test has been completed, this water-bath is again raised to 130° F. by placing the lamp underneath, and is readily achieved while the petroleum-cup is being emptied, cooled, and refilled with a fresh sample to be tested. The lamp is then turned on its swivel from under the apparatus, and the next test is proceeded with.

The test-lamp is prepared for use by fitting it with a piece of flat plaited candle-wick, and filling it with colza- or rape-oil up to the lower edge of the opening of the wick-tube. The lamp is trimmed so that, when lighted, it gives a flame of about 0·15 in. diameter, and this size of flame, which is represented by the projecting white bead *i* on the cover of the oil-cup, is readily maintained by simple manipulation from time to time with a small wire trimmer.

When gas is available, it may be conveniently used in place of the little oil-lamp, and for this purpose, a test-flame arrangement for use with gas may be substituted for the lamp.

The bath having been raised to the proper temperature, the oil to be tested is introduced into the petroleum-cup, being poured in slowly until the level of the liquid just reaches the point of the gauge which is fixed in the cup. In warm weather, the temperature of the room in which the samples to be tested have been kept should be observed in the first instance, and if it exceeds 65° F., the samples should be cooled down to about 60° F., by immersing the bottles containing them in cold water, or by any other convenient method. The lid of the cup, with the slide closed, is then put on, and the cup is placed in the bath. The thermometer in the lid of the cup has been adjusted so as to have its bulb just immersed in the liquid, and its position is not under any circumstances to be altered. When the cup has been placed in the proper position, the scale of the thermometer faces the operator.

The test-lamp is then placed in position upon the lid of the cup, the lead-line or pendulum, which has been fixed in a convenient position in front of the operator, is set in motion, and the rise of the thermometer in the petroleum-cup is watched. When the temperature has reached about 66° F., the operation of testing is to be commenced, the test-flame being applied once for every rise of one degree, in the following manner:—The slide is slowly drawn open while the pendulum performs three oscillations, and is closed during the fourth oscillation.

If it is desired to employ the test apparatus to determine the flashing-points of oils of very low volatility, the mode of proceeding is to be modified as follows:—The air-chamber which surrounds the cup is filled with cold water, to a depth of 1½ in., and the water-bath is filled as usual, but also with cold water. The lamp is then placed under the apparatus, and kept there during the entire operation. If a very heavy oil is being dealt with, the operation may be commenced with water previously heated to 120° F., instead of with cold water.

The Schedule omits to state that the length of the pendulum to be used shall be 2 ft. from the point of suspension to the centre of gravity of the weight.

The "flashing-point" of an oil is understood to mean the temperature at which the escaping vapour will momentarily ignite; the "burning-point" is that at which the oil takes fire and burns. Lubricating-oils should always flash above 120° (250° F.), and take fire at a considerably higher temperature. Animal and vegetable oils do not vapourize, but decompose at high temperatures, beyond the range of a water-bath. A comparison of petroleum, sperm-oil, and lard-oil showed the following respective figures:—Flashing-point: 118° (245° F.), 219° (425° F.), 246° (475° F.); igniting-point: 143° (290° F.), 252° (485° F.), 274° (525° F.); burning-point: 149° (300° F.), 260° (500° F.), 274° (525° F.) The standard animal and vegetable lubricating-oils, and all mineral oils of good body and high sp. gr., decompose or vapourize only at temperatures exceeding that of steam in ordinary engines, the former usually and latter sometimes bearing steam at locomotive pressure. As to congealing-points, these have been mostly given in the case of each oil in the preceding pages. Under Ice, pp. 1134–5, will be found a number of freezing-mixtures useful for testing such points. The precise value of any lubricating material is best ascertained by one of the many forms of apparatus devised for this purpose, such as McNaught's, Napier's, Ingham and Stapper's, Bailey's, Ashcroft's, Crossley's, Van Cleve's, Hodgson's, &c., fully described and figured in Thurston's work quoted at the end of this article.

The suitability of a lubricating medium depends upon the character of the work being done, and is not constant. In order to procure the nearest possible approach to what is required for special purposes, many compounds are now in the market, being mainly mixtures of mineral and animal or vegetable oils in proportions calculated to develop the particular characteristics required. The general experience gained of various oils used for lubricating tends to the following results:—(1) A mineral oil flashing below 149° (300° F.) is unsafe, on account of causing fire; (2) a mineral oil evaporating more than 5 per cent. in 10 hours at 60° (140° F.) is inadmissible, as the evaporation creates a viscous residue, or leaves the bearing dry; (3) the most fluid oil that will remain in its place, fulfilling other conditions, is the best for all light bearings at high speeds; (4) the best oil is that which has the greatest adhesion to metallic surfaces, and the least cohesion in its own particles: in this respect, fine mineral oils are 1st, sperm-oil 2nd, neatsfoot-oil 3rd, lard-oil 4th; (5) consequently the finest mineral oils are best for light bearings and high velocities; (6) the best animal oil to give body to fine mineral oils is sperm-oil; (7) lard- and neatsfoot-oils may replace sperm-oil when greater tenacity is required; (8) the best mineral oil for cylinders is one having sp. gr. 0·893 at 15½° (60° F.), evaporating-point 288° (550° F.), and flashing-point 360° (680° F.); (9) the best mineral oil for heavy machinery has sp. gr. 0·880 at 15½° (60° F.), evaporating-point 229° (443° F.), and flashing-point 269° (518° F.); (10) the best mineral oil for light bearings and high velocities has sp. gr. 0·871 at 15½° (60° F.), evaporating-point 218° (424° F.), and flashing-point 262° (505° F.); (11) mineral oils alone are not suited for the heaviest machinery, on account of want of body, and higher degree of inflammability; (12) well purified animal oils are applicable to very heavy machinery; (13) olive-oil is foremost among vegetable oils, as it can be purified without the aid of mineral acids; (14) the other vegetable oils admissible, but far inferior, stated in their order of merit, are gingelly-, ground-nut-, colza-, and cotton-seed-oils; (15) no oil is admissible which has been purified by means of mineral acids.

The results of W. H. Watson's experiments upon the corrosive action of various oils on copper and iron surfaces are worthy of reproduction here. After 10 days' exposure of copper to the action of the several oils named below, the effects were evidenced by the following quantities of copper held by them:—Linseed-oil, 0·3000 gr.; olive-oil, 0·2200 gr.; neats'-foot-oil, 0·1100 gr.; almond-oil, 0·1030 gr.; seal-oil, 0·0485 gr.; colza-oil, 0·0170 gr.; sperm-oil, 0·0030 gr.; paraffin, 0·0015 gr. Iron subjected to similar treatment for 24 days was affected to the following extent:—Neats'-foot-oil, 0·0875 gr.; colza-oil, 0·0800 gr.; sperm-oil, 0·0460 gr.; lard-oil, 0·0250 gr.; olive-oil, 0·0062 gr.; linseed-oil, 0·0050 gr.; seal-oil, 0·0050 gr.; castor-oil, 0·0048 gr.; paraffin, 0·0045 gr.; almond-oil, 0·0040 gr.; special lubricating-oil, 0·0018 gr. These results show that the extent of the action of any oil on one metal is no guide to the degree in which it will affect another metal.

Boiling, Oxidizing, and Vulcanizing.—Certain oils (as shown by the table on p. 1467), possess a much greater "drying" tendency than others, that is to say, on exposure to the air, they absorb oxygen, lose their greasiness, and ultimately become dry and hard. This property is availed of in the manufacture of linoleum (see p. 1001), of printing-ink (see p. 1170), of paints (see Paint), of oil-varnishes (see Varnish), &c. The oxidizing tendency is much increased by three separate processes:—(1) By exposure to the air in very thin layers, as detailed under Floorcloth, p. 1002; (2) by heating, or, as it is improperly termed, "boiling," which has been noticed under Ink, p. 1171, and will receive further attention here; and (3) by the addition of "driers" while hot.

The "boiling" process described on p. 1171, is still widely adhered to by printing-ink makers, and is declared to be indispensable for the manufacture of lithographic ink. A great improvement consists in the substitution of a steam-jacket for an open fire, and the blowing-in of air. The pan is best of copper, circular in shape, with an equal depth and diameter, and a rounded bottom. It is surrounded with an iron steam-jacket for about half its depth. Both pan and jacket are made to withstand a pressure of 40 lb. a sq. in. The top of the pan is closed by a dome rivetted to it, provided with a man-hole and a stuffing-box, the latter for admitting the shafts of a couple of fans, made to rotate in opposite directions, and intersecting each other. From a cupola on the dome, issues a 3-in. pipe for conveying away the vapours, to be treated as described under Floorcloth, p. 1004. The lower part of the pan is fitted with a 1-in. pipe, for introducing air under pressure through the jacket and into the pan. The oil (linseed) is run from a tank holding one batch for boiling (about 2 tons), when it has settled during 4–5 hours. The waste steam from the jacket passes through a coil of 1½-in. iron pipe in this tank, thus warming the oil somewhat, and tending to cause a separation of impurities. The oil runs at a temperature of about 35° (95° F.) into the pan, when steam is admitted to the jacket, and the fans are started. When the steam in the jacket reaches a pressure of 35 lb. a sq. in., the air-blast may be admitted. The heat and blast are maintained for about 4 hours; the pressure of steam in the jacket must never be allowed to descend below 30–35 lb. a sq. in., while the admission of air is not gauged, but is kept up as long as the oil does not froth over into the condenser. The oil is run out by a 2-in. tap in the centre of the bottom, joined to pipes connected by running joints, the same tap being used for the admission of the air, and a second tap being provided beyond.

When driers are used, as they almost always are, the oil drawn from the pan is allowed to rest for some time, so that the major part of the driers may settle out, and may be available for re-use. The action of the driers is various. Sulphate of zinc simply facilitates the separation of the vegetable albumen and mucilage present in the oil, and which impair its drying; other substances, such as peroxide of manganese, peroxide of iron (umber), protoxide of lead (litharge), and other lead salts, either impart oxygen to the oil, or, dissolving in the oil, and being themselves oxidizable in combination, operate catalytically in increasing its oxygen-absorbing power. The recipes for the composition of the driers are kept secret; but when using the steam process, the admixture of catalytic substances and litharge may be varied to produce any desired degree of colour, without affecting the drying, the shade deepening with the increase of the lead salt. The driers used must be of exceeding fineness, such as is only obtainable by running them with water through a series of settling-tanks.

It has been stated by C. W. Vincent, before the Society of Arts, that the air does nothing towards making the oil "drying." Linseed-oil heated for 3 days consecutively at a high temperature, in presence of the air, but without driers, required the same time to dry as the raw oil from which it was prepared, but the "body" was much increased. Heating alone for the same time with only surface exposure to air, produced no such increase of body; the oil became more greasy, less penetrative, and less drying.

In sending boiled oil on long journies, it is advisable always to add a proportion of raw oil, to avoid the risk of its becoming "fatty," and not free enough in working; for a 3-months' journey, and boiled oil less than 1 month old, the proportion of raw oil may be 25 per cent.

Dr. Domingos Freire has recently stated that the oxidation of oils is not due alone to the action of oxygen, but also to a fungus, which he names *Microclados olecrum*, a microphyte which cannot develop in oils containing phenol (carbolic acid), arsenious acid, or copper sulphate.

Some remarks on the vulcanizing of oils will be found under the heading of Indiarubber Manufactures, pp. 1161–2. A substance possessing many of the characteristics of indiarubber is made by mixing flowers of sulphur with hot linseed-oil. The oil is said to be heated in an iron pot over a fire to about 232° (450° F.) and is then removed, and placed under a hood for conveying vapours to the chimney. When the oil has cooled to about 176½° (350° F.), the sulphur is thrown in. The odours emitted are most offensive, and need every precaution for their rendering innocuous. The product is used as an adulterant of or substitute for indiarubber.

Imports of Oils.—The imports of the various oils into the United Kingdom in 1879 were as follows:—

Train-oil or blubber: from British N. America, 10,059 tuns, value 268,068*l.*; United States, 3244 tuns, 75,350*l.*; N. whale fisheries, 1717 tuns, 40,746*l.*; Norway, 1303 tuns, 36,025*l.*; Spain, 449 tuns, 11,552*l.*; other countries, 1177 tuns, 30,073*l.*; total, 17,949 tuns, 461,814*l.*

Spermaceti or head-matter: from the United States, 1527 tuns, 85,793*l.*; Australia, 351 tuns, 20,341*l.*; Chili, 96 tuns, 5816*l.*; other countries, 273 tuns, 15,540*l.*; total, 2247 tuns, 127,490*l.*

Animal oils: from the United States, 94,449 cwt., 166,492*l.*; France, 4919 cwt., 10,479*l.*; other countries, 7781 cwt., 11,134*l.*; total, 107,149 cwt., 188,105*l.*

Palm-oil: (foreign) from W. coast Africa not particularly designated, 657,142 cwt., 996,294*l.*; Fernando Po, 6460 cwt., 10,310*l.*; Portuguese possessions, 3544 cwt., 5475*l.*; Gold Coast, 202,151 cwt., 310,301*l.*; British W. Africa, 5835 cwt., 8894*l.*; other countries, 6197 cwt., 13,514*l.*; total, 881,329 cwt., 1,344,788*l.*

Castor-oil: from the British E. Indies, 105,854 cwt., 204,845*l.*; other countries, 2392 cwt., 5363*l.*; total, 108,246 cwt., 210,208*l.*

Coco-nut-oil: from Ceylon, 111,318 cwt., 216,358*l.*; Madras, 59,479 cwt., 122,460*l.*; Mauritius, 12,252 cwt., 23,323*l.*; Bombay, 9134 cwt., 20,342*l.*; other countries (including "Sydney" and "Cochin"), 7808 cwt., 15,582*l.*; total, 199,991 cwt., 398,065*l.*

Olive-oil; from Italy, 16,474 tuns, 763,450*l.*; Turkey, 4681 tuns, 198,253*l.*; Greece, 3376 tuns, 141,484*l.*; Spain, 411 tuns, 18,559*l.*; France, 331 tuns, 17,127*l.*; Egypt, 302 tuns, 12,782*l.*; other countries, 623 tuns, 27,366*l.*; total, 26,198 tuns, 1,179,021*l.*

Seed-oils of all kinds: from Germany, 10,641 tuns, 334,909*l.*; France, 1892 tuns, 71,079*l.*; United States, 1257 tuns, 35,194*l.*; Holland, 1071 tuns, 35,749*l.*; Belgium, 626 tuns, 19,000*l.*; other countries, 378 tuns, 13,044*l.*; total, 15,865 tuns, 508,975*l.*

Chemical, essential, or perfumed oils: from Italy, 203,881 lb., 62,536*l.*; France, 108,399 lb., 35,522*l.*; United States, 82,544 lb., 37,522*l.*; China, 62,711 lb., 16,534*l.*; British E. Indies, 59,207 lb., 13,782*l.*; Germany, 27,667 lb., 11,788*l.*; Turkey, 1366 lb., 9842*l.*; other countries, 17,028 lb., 7014*l.*; total, 562,803 lb., 194,540*l.*

Unenumerated oils: from France, 21,481*l.*; United States, 18,976*l.*; Australia, 16,350*l.*; Belgium, 12,021*l.*; other countries, 15,162*l.*; total, 83,990*l.*

Petroleum—unrefined: from the United States, 1765 tuns, 13,101*l.*; other countries, 128 tuns, 440*l.*; total, 1893 tuns, 13,541*l.* Refined: from the United States, 42,478,427 gal., 1,349,616*l.*; other countries, 324,828 gal., 19,377*l.*; total, 42,803,255 gal., 1,368,993*l.*

Prices of Oils.—The approximate London market values of the principal oils and fats of commerce are as follows:—Tallow: St. Petersburg Y.C., new, 37–45*s.* a cwt., old, 35–43*s.*; Australian beef, 35*s.* 6*d.*–37*s.*; sheep, 38*s.*–39*s.* 6*d.*; South American sheep, 36–42*s.*, beef, 39*s.* 6*d.*–42*s.*; North American, 35–40*s.*; British rough fat, 1*s.* 6*d.*–1*s.* 7*d.* a stone, town fat, 38*s.* 3*d.* a cwt., melted stuff, 27*s.* 6*d.* a cwt., rough melted stuff, 14*s.* a cwt. Spermaceti: refined, 1*s.* 3*d.*–1*s.* 4*d.* a lb.; American 1*s.*–1*s.* 2*d.* Seed-oil: pale, 29–30*l.* a tun; yellow to tinged, 25*l.*–29*l.* 10*s.*; brown, 24–26*l.* Sperm-oil: 60–68*l.* a tun. Cod-oil, 27*l.* 10*s.*–29*l.* a tun. Whale-oil: pale, 26–29*l.* a tun; yellow, 25–28*l.*; brown, 20–26*l.* Cod-liver oil, 2*s.* 9*d.*–5*s.* a gal. Lard-oil, 38–44*l.* a tun. Tallow-oil, 31–35*l.* a tun. Castor-oil: E. Indian, 4½–5¼*d.* a lb.; inferior, 4¼–4¾*d.* Olive: Gioja, 43*l.* a tun; Levant, 45–46*l.*; Spanish, 46–49*l.*; Sicily, 46*l.*-46*l.* 10*s.* Coco-nut-oil: Cochin, 39–50*l.* a tun; Ceylon, 36*l.* 15*s.*–47*l.*; Mauritius, 37*l.* 10*s.*–46*l.* Palm-oil: fine Lagos, 36*l.* 10*s.*–37*l.* a tun; palm-kernel oil, 36–38*l.* Linseed-oil, 24*l.* 2*s.* 6*d.*–28*l.* 10*s.* a tun. Rapeseed-oil: English pale, 31*l.* 15*s.*–32*l.* a tun; brown, 29*l.* 15*s.*–30*l.* Cotton-seed-oil: refined, 26–30*l.* a tun. Almond-oil: essential, 20–30*s.* a lb.; expressed, 1*s.* 10*d.*–2*s.* Aniseed-oil, essential, 9–11*s.* a lb. Cajuput-oil: essential, 3*s.* 6*d.*–4*s.* 6*d.* a bottle. Caraway-oil: essential, 2*s.* 6*d.*–6*s.* a lb. Cassia-oil: essential, 2*s.* 8*d.*–4*s.* 8*d.* a lb. Cinnamon-oil: essential, 2*s.* 2*d.*–5*s.* 6*d.* an oz.; leaf, 1½–1¾*d.* Citronella-oil: essential, 3–5½*d.* an oz. Clove-oil: essential, 8*s.* 9*d.*–9*s.* a lb. Croton-oil, 2½–2¾*d.* an oz. Ginger-grass-oil: essential, 2½–3½*d.* an oz. Lavender-oil: essential, 7*s.* 6*d.* a lb. Lemon-oil: essential, 3*s.*–5*s.* 6*d.* a lb. Lemon-grass-oil: essential, 2¾–4½*d.* an oz. Mace-oil: expressed, 6–7*d.* an oz. Neroli-oil: essential, 6–9*s.* an oz. Nutmeg-oil: essential, 2¼–4*d.* an oz. Orange-oil: essential, 5–7*s.* a lb. Otto of rose, 15–35*s.* an oz. Patchouli, 1*s.* 6*d.*–3*s.* an oz. Peppermint-oil: essential, American fine, 10*s.*–15*s.* 6*d.* a lb.; English, 21–23*s.* Pimento: essential, 12*s.* 6*d.* a lb. Rosemary-oil: essential, 3*s.* 6*d.* a lb. Sassafras-oil: essential, 1*s.* 9*d.*–3*s.* 9*d.* Spearmint-oil: essential, 13*s.* 6*d.* a lb. Thyme-oil: essential, 5*s.* a lb.

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(See Bones; Candles; Coal-tar Products; Drugs; Floorcloth; Ink; Nuts; Paraffin; Perfumes; Photometry; Pigments and Paint; Resinous Substances; Soap; Varnish; Wax).

PAPER (Fr., *Papier*; Ger., *Papier*).

The manufacture of paper may be conveniently divided into two main sections:—(1) the materials which are or may be employed for the purpose; and (2) the methods by which those materials are converted into paper and finished for the market.

The Raw Materials.—In former days, paper was manufactured exclusively from rags, either linen or cotton; but the increased demand for it, for printing and other purposes, has made it absolutely necessary that some more abundant source should be found. Paper is composed chiefly of cellulose, in a more or less purified state, and as this forms the basis or groundwork of all vegetable life, it is obvious that the supply of raw materials is practically unlimited. But as cellulose in nature is found intimately associated with colouring and incrusting matters, the removal of which involves the use of comparatively expensive chemicals, the paper-manufacturer, in fixing his choice on a raw material, must take into consideration not only its first cost, but also the amount and character of such combined substances, and the comparative ease or difficulty with which they can be removed, in order to secure the cellulose in a pure state.

The following list contains the more important materials actually in use for manufacturing paper:—Rags, linen and cotton; flax; hemp; esparto or alfa; woods of various kinds; straw; old ropes; jute; old sacking; manilla hemp; canes and bamboo; and *Adansonia* fibre. To these, might be added an almost innumerable list of other substances which are used to a very limited extent. The production and commerce, and in many cases the structure, of the vegetable fibres, will be found described at length in the article on Fibrous Substances, pp. 909–1000. In this article, attention will be confined to the paper-making qualities of the chief materials.

Rags.—Though, strictly speaking, not raw material, the substance of the rags having undergone a purifying treatment before being manufactured, they may conveniently be classed as such here. Rags may be obtained in an almost endless variety, differing according to the locality in which they are gathered. They are generally sent to the paper-maker packed in bales, having been to a certain extent sorted. For trade purposes, rags are divided into a large number of classes or grades, distinguished by various letters. When rags are stored in large quantities, care should be taken that they are perfectly dry, as, if at all damp, they are liable to fire, from the heat developed by slow decomposition. Nearly all the incrusting and colouring matters having been removed from the cotton or flax from which the rags are made, in the textile manufacturing processes, it follows that they consist of tolerably pure cellulose, and therefore yield a large percentage of fibre. This, together with the fact that they are readily bleached to a very pure white, the resulting fibre being exceedingly strong, renders them a most valuable material. Alone, they are used for only the finest qualities of paper, but they are often mixed with inferior fibres to give strength.

Flax.—Raw flax being in great demand for textile purposes, cannot be economically manufactured directly into paper. Such portions, however, as are rejected by the spinner can thus be made use of. (See Fibrous Substances, pp. 964–978; Linen Manufactures, pp. 1246–1255).

Hemp.—Hemp is generally used only in the form of old ropes, &c. (See Fibrous Substances, pp. 934–8; Rope.)

Esparto.—This grass is perhaps, next to rags, the most important material used by paper-makers in this country. The consumption has steadily increased since it was first introduced by Routledge in 1856. Various qualities of esparto are known, the best of which is imported from Spain. Slightly inferior qualities are brought from various districts in N. Africa. (See Fibrous Substances, pp. 978–981.) The amount of fibre in esparto varies according to the locality in which it is grown, Spanish yielding more than any other kind. According to Dr. Hugo Müller, Spanish esparto contains 49·52–50·19 per cent. of cellulose, and African, 47·55–50·16 per cent. This, of course, does not represent the amount of fibre actually obtainable by the manufacturer, a considerable loss occurring during the various processes to which it is subjected. The yield of bleached fibre obtained in practice probably does not much exceed 40 per cent.

Wood.—Two varieties of pulp suitable for paper manufacture may be obtained from wood, viz. mechanically and chemically prepared pulps. Almost any kind of wood may be used, those being chosen which most readily yield a pulp by suitable treatment. Hitherto wood-pulp has not been very largely employed by paper-makers in this country, chiefly because there has been a plentiful supply of other material; but in America and on the Continent, large quantities are consumed every year. What is used here comes principally from Sweden and Norway, and may be obtained either bleached or unbleached. When properly prepared, wood-pulp is a very valuable material, and may be used either alone or mixed with other fibres in papers of good quality. The amount of cellulose differs in various woods, running from 39·47 (oak) to 56·99 (fir).

Straw.—As a material for mixing with other fibres, straw-pulp is in great demand. For this purpose, it is valuable; but if used alone, only very inferior paper can be made from it. Though straw does not yield a very large amount of fibre, yet the supply of it is in most districts pretty considerable and constant. The varieties generally used are oat, wheat, rye, and barley; of these, rye is considered the most suitable, on account of its yielding the largest amount of fibre; next in importance comes wheat. The amount of actual cellulose in straw is comparatively large (say 49·00), but probably not more than 35 per cent. is actually obtained as pulp, the reason being that a large portion of the cellulose is in the state of loosely aggregated cellular tissue, and that much of this is lost in the treatment.

Jute.—Fibre from jute possesses properties that would render it extremely valuable as a paper-making material, if means could be devised whereby it could be economically bleached to a good white, at the same time preserving the strength of the fibre. Hitherto, this has not been accomplished, hence jute has received only a limited application, having been used chiefly for papers in which a great degree of whiteness is not essential. Jute is usually obtained in the form of "butts" or "cuttings," these being the portions (root-ends, &c.) rejected by the textile manufacturer. (See Fibrous Substances, pp. 940–5; Jute Manufactures, pp. 1176–1186).

Bamboo and Cane.—Much attention has been given of late years to the bamboo (see Fibrous Substances, pp. 920–1) as a probable source of paper-making material. It has been made the subject of a series of very carefully-conducted experiments by Thos. Routledge, and is highly recommended by him. Before the subject was taken up by him, many attempts had been made to obtain pulp from the bamboo, but they were economically unsuccessful, as the large amount of silica present rendered it necessary to act upon it with very strong solutions of caustic soda, at high pressure (150–160 lb. a sq. in.). The difficulties of such a treatment are well-nigh insurmountable. In all these trials, it was the well-developed and matured plant that was used. If, instead of this, the young and succulent shoots are taken, before the plant has had time to develop much woody substance or silicious covering, the case is materially altered. These shoots are very easily reduced to a suitable paper-making material, by simple digestion in comparatively weak solutions of alkali, at the ordinary atmospheric pressure. Before this treatment, however, Routledge proposes to free the plant from a large quantity of sap and juice by crushing between fluted rollers; this considerably facilitates the subsequent boiling operation. Owing to the fact that the young green shoots contain about 75 per cent. of moisture, and that the remainder yields only 60 per cent. of fibre, it would be necessary to partially prepare the fibre at or near the spot where the bamboo is cultivated. The quality of the pulp produced is excellent. The bamboo grows with enormous rapidity, sometimes at the rate of even 1 ft. in a single night, and according to Routledge, if the cutting of the shoots be attended to carefully, the plant will continue year after year to throw out fresh ones. The variety to which attention has hitherto been directed is *Bambusa vulgaris*; there are, however, other members of the same family which would perhaps be equally suitable. There appears not the slightest doubt, that if Routledge's conclusions are correct, we have here an almost boundless and very valuable source of material. Unfortunately, the opinions of experienced men differ somewhat on the question; but notwithstanding this, the subject is one that deserves very careful attention, as it is becoming obvious that in the future, perhaps the near future, the supply of esparto, to which the paper-makers of this country now look for the largest proportion of their raw material, will be considerably smaller than at present, and may in fact ultimately cease altogether. That it is steadily diminishing, is evident, and this, together with the fact that it takes about 14 years to raise from seed, if indeed it could be conveniently done at all, renders it absolutely necessary that manufacturers should devote more attention to probable new sources of material.

In America, a considerable quantity of paper is annually made from pulp prepared from cane (*Arundinaria macrosperba*). It grows profusely in the lowlands of the Mississippi, and along the rivers of N. and S. Carolina, and, labour being cheap in those districts, it can be very economically gathered. The fibre, which is sold to the paper-maker in the form of half-stuff, is obtained by a very curious process. The cane, cut into pieces, is tightly packed into strong cast-iron cylinders, called "guns," about 22 ft. long and 1 ft. in diameter, fitted with strong ends, and provided with a very strong dome for containing steam. Steam is sent into these cylinders until a pressure of about 180 lb. a sq. in. is indicated; this is kept up for about 15 minutes; the end of the cylinder is then suddenly opened, and the whole mass of cane is forced violently out against a target provided in case of accident. While in the gun, the pores of the cane are filled with the highly compressed steam, which, on reaching the outer air, expands rapidly, with a loud report, like that of a cannon, with the effect of thoroughly disintegrating the cane, and reducing it to a fibrous state. It appears that the effect is due partly to chemical and partly to mechanical action. The fibre thus produced is well washed, and beaten under revolving rolls fitted with knives, similar to those used in the beating-engines of paper-mills.

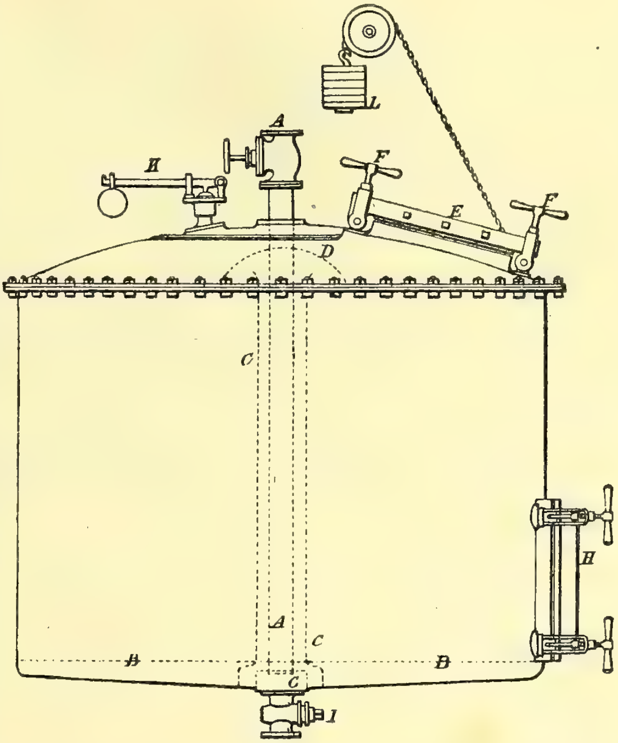
Waste paper.—A very important source of material is waste paper, large quantities of which are remanufactured. Any kind of old paper can thus be utilized, and as it has already undergone the necessary treatment, very little more is required to prepare it. It generally goes by the names of "broke" or "imperfections."

MANUFACTURE.—*Treatment of Esparto.*—As by far the largest proportion of the paper manufactured in Great Britain is made, if not entirely, at least largely, of esparto, and as the processes to which this fibre is subjected are typical of the treatment which other fibres undergo, with such exceptions as will be pointed out in their proper place, the methods in general use for the preparation of this important material will fitly occupy the foremost place.

The first process is the removal of accidental impurities, such as pieces of weed, root-ends, &c., which, from their nature, are with great difficulty boiled and bleached, and would not only therefore tend to deepen the colour of the bulk of fibre produced, but would be liable to appear subsequently in the finished paper as dark-coloured specks, technically known as "sheave." This treatment, which is called "dry-picking," in contradistinction to a subsequent process, known as "wet-picking," is generally performed by girls, who work at separate tables placed in a long row. A portion of the table set apart to each girl is covered with a very coarse iron-wire gauze, on which small bunches at a time of esparto are spread, to enable the worker more readily to see the imperfections, and through which small impurities, such as sand, pass away. It has been proposed to economize time and labour by using a machine for the purpose of dry-picking. One of the best machines of the kind is that made by Masson and Scott. In it, the grass is first put through a conical willow, where all the dust is removed by a blast, and carried away into a separate chamber. The grass so purified is brought forward on an endless travelling felt, at each side of which, girls are placed to remove the roots and other objectionable bodies. The grass so sorted is then taken to the boiler-house.

Boiling.—There are several sorts of boilers in use, but only two call for special notice. The one in ordinary use is shown in Fig. 1049. The grass is put in by the door E, which can be firmly fastened down by the screws F. The steam enters by the pipe A, which goes a little below the perforated bottom B. Surrounding the steam-pipe is a wider pipe C, open at the top, and made slightly trumpet-shaped, also open at the bottom, below the false bottom. It carries at its lower end a kind of shoulder, on which the false bottom rests. The enlarged part of this tube beyond the shoulder has two or more openings G, through which the liquor can freely pass. The action of the boiler is as follows:—The steam from the pipe A heats the liquor that has drained from the grass through the perforations in the false bottom B, and, forcing it up the wide pipe C, causes it to strike against the dome or bonnet D, and distribute itself again over the grass. This is technically called "vomiting." The boiler is emptied by the door H, and the liquor is run off by the tap I. The boilers are usually supplied with a safety-valve K. The weights L are for convenience in lifting the door E. While the boiler is being filled with grass, the vomit is usually kept going; this has the effect of softening the grass, and allowing it to be more closely packed.

1049.



This form of boiler is not suitable for use with very high-pressure steam. Under such circumstances, it is slightly modified. In Sinclair's patent high-pressure boiler, there are two false bottoms communicating with each other by means of short pipes. The vomit-pipe extends as far as the lower partition, and the steam enters at the bottom of the boiler. In Rœckner's, the compartment formed by the perforated bottom communicates with the top of the boiler by means of a pipe outside, which has a bend in it, forming a complete circle. This is with the object of keeping the pipe always full of liquor. The vomit is produced by steam entering the pipe at the bottom of the bend. In some mills, rotary boilers are employed for esparto, but their use is far from being general.

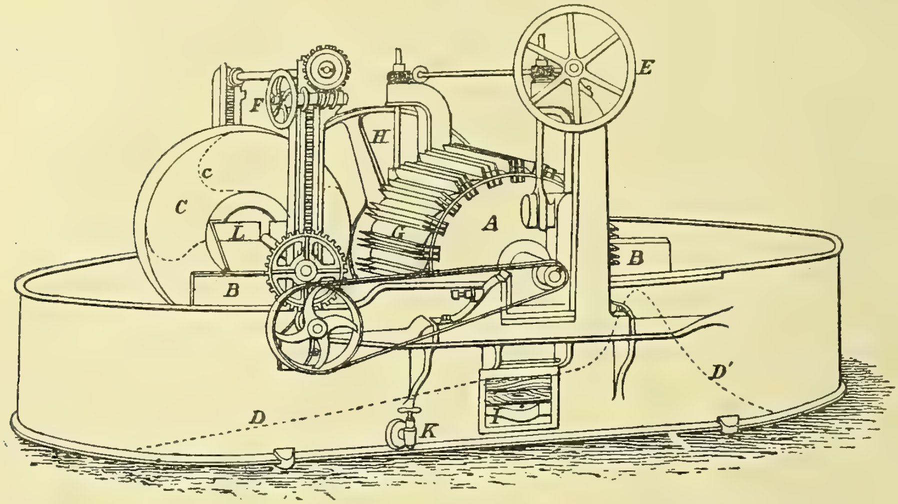
It is impossible to give anything like exact figures for the amount of caustic soda necessary to properly boil esparto, so much depending upon the quality of the grass, the style of boiler employed, and the class of paper proposed to be manufactured. The same effects may sometimes be produced by boiling with a small quantity of caustic soda for a long time, or at a high pressure; or for a shorter time, or at a lower pressure, with a larger proportion.

The proportion given by Routledge, to whom the development of the esparto process is due, is 10 per cent. of pure caustic soda. In respect to the boilers, it is said that Rœckner's form is the most economical, as, other things being equal, a smaller quantity of soda is sufficient. The time required is also subject to much variation, some mills boiling for four and others for eight hours.

Washing.—The boiling being completed, the steam is turned off, the lid is removed, and the almost black liquid, highly charged with matter (resin, silica, &c.) extracted from the grass, is run away to a large store-well. Water is now run in, the lid is fastened on, and steam is turned on again for a short time. The liquor from this washing is also run into the store-well. The grass is next removed by the bottom door H, and is carried away in trucks to the "wet-picking" house, where it is again overhauled, and any unboiled portions are removed. In some mills, where a great degree of purity is not required in the paper, this sorting process is dispensed with.

It is now taken to the breaking- or washing-engine, where it is reduced to pulp, and washed free from the liquor remaining after the partial washing in the boiler. The construction of the engine will be readily understood by reference to Fig. 1050. It consists essentially of a large rectangular vessel, with oval ends, in the centre of which is a partition B, technically called the "mid-feather." The roll A, carrying the knives G, and driven from the wheel H, revolves in one of the compartments formed by the mid-feather. In this compartment, the floor is inclined so as to bring the pulp well under the roll, as shown by the dotted line D. Immediately under the roll, is what is called the "bed-plate," the end of which is seen at I, extending up to the mid-feather, and fitted with knives, similar to those in the roll A. The distance between the roll and the bed-plate can be altered by means of the handle E. After passing between the roll and the bed-plate, the pulp flows down the peculiar elevation known as the "back-fall," shown by the dotted line D^1, and finds its way round to the other side of the mid-feather. On the inclined part of the floor, and just in front of the bed-plate I, is placed a grating for the purpose of catching small pieces of stone, and other heavy substances that may have found their way into the pulp. There is generally a similar grating, but with rather finer openings, on the other side of the mid-feather. The whole engine is usually made entirely of iron in one casting, though in some cases, the sides are of iron and the floor is of wood. The drum C serves to run off the wash-water. It is divided into four or five compartments by the partitions shown by the dotted lines *c*. The centre of the drum is a conical tube, the narrow end of which is towards the mid-feather; this causes the water to flow into the spout L, and down the mid-feather, which is made hollow at this part for the purpose. Or the water, as in the older forms, may be conducted along a trough placed across the engine. The sides of the drum are commonly made of mahogany, as this is found to stand the action of the soda better than any other wood. The circumference is covered with fine copper gauze, backed with a very much coarser material. The drum can be raised or lowered by the small wheel F, and it is driven by a belt from the shaft that bears the roll. The pulp is discharged through a valve in the bottom. The tap K may be used for the purpose of cleaning the engine. The breaker is first half-filled with water, and then the charge of grass is put in. In about 20 minutes, it is sufficiently broken up, and the water is then run off by the washing-drum, fresh water at the same time running in, in order to ensure a thorough washing. At this stage of the manufacture, the pulp goes by the name of "half-stuff."

1050.



Bleaching.—The next step in the process is to bleach the pulp. For this purpose, it is run from the breaker into a "poacher," placed at a slightly lower level. The poacher very closely resembles the breaker, except that it is somewhat larger, and contains, instead of knives, a number of cast-iron paddles on the circumference of a hollow drum, with which to thoroughly stir the pulp. Bleaching-liquor, usually made in another part of the mill, by dissolving bleaching-powder in water, is now run in, and the whole is thoroughly mixed up by means of the paddles. It is the practice in some mills to assist the bleaching operation by the addition of a small quantity of an acid, either hydrochloric or sulphuric. Other manufacturers attain the same end by heating the mass with a jet of steam to about 32° (90° F.); others, again, put in a small quantity of bicarbonate of soda, a portion of the carbonic acid of which has the same effect as hydrochloric or sulphuric acids.

The quantity of bleaching-powder necessary is subject to considerable variation, depending greatly upon the quality of the grass, and the extent to which it is boiled; 12 lb. per cwt. of esparto may be considered a fair average quantity. After remaining in the poacher for about 2 hours, the almost perfectly white pulp is run off into large chests or drainers, and allowed to remain there for about 8 hours, or longer if convenient. The chests are supplied with perforated bottoms, through which a large proportion of the liquor drains away. It is said that the action of light assists the bleaching process, and for this reason, the chests are often placed in an exposed position. The drained pulp is next transferred to hydraulic presses, where most of the liquor left in is got rid of.

The preceding method of treating the grass is the one usually adopted, but, in some cases, other systems are in use. Thus, instead of breaking and bleaching in separate engines, some manufacturers perform the two operations in the breaker, which, in this case, is provided with two drums, one covered with coarse gauze for removing the liquor from the boiling operation, and the other for removing the excess of bleach, when the pulp is considered white enough, which usually happens in about 2½ hours. The gauze on the drum for removing the bleach is finer, because at the end of the operation the pulp is much finer, and would therefore pass in considerable quantity through a coarse one. In this modified system, the pulp is not pressed, but, after the excess of bleach has been washed away through the drum, is run off into the "beaters."

Beating.—Beating-engines differ but little in appearance from breaking-engines. The revolving roll, however, carries more knives, and is let down much nearer to the bed-plate, in order to complete the process only partially done in the breakers, of reducing the esparto to a sufficiently fine pulp. It is in the beaters that the final preparations of the pulp are made, and much care is necessary in their management. The bleached pulp from the hydraulic presses, or direct from the breakers, according to the system of bleaching employed, is placed in the beaters together with a quantity of water carefully filtered through a bag of woollen felt.

Immediately after furnishing the engine, a quantity of some loading or filling material is run in. The one usually employed, as being the most economical, is kaolin or China-clay (see pp. 635–9). The addition of China-clay in moderate quantity can hardly be looked upon as an adulteration, since it serves to close up the pores of the paper, and enables it to take a good surface. Of course, if added largely, it tends to weaken the paper. The clay is usually made into a fine milk with water, by being mixed in vessels provided with revolving agitators, placed above the level of the beaters. Before being run into the engine, it is carefully sieved through fine wire-cloth. Occasionally papers are made without any clay. Other filling materials have been proposed, and several others are in actual use, the chief of these being precipitated sulphate of lime, or "pearl-hardening;" this, however, is used only in the finest class of papers, it being too expensive for ordinary use. No rule can be given for the amount of loading material to be used, as papers are made with quantities varying from 5 to 15 per cent., and even more. When the clay or other substance exceeds 15 per cent., it certainly cannot be to the advantage of the user.

The quality of the water is a matter of the utmost importance in the manufacture of fine papers. Above all things, it should be free from suspended matter, and from dissolved iron. While much of the former can be removed by settling in large ponds, and by careful filtration, the latter cannot be economically eliminated, and is liable to be precipitated in the fibre, thus injuriously modifying the colour of the paper.

The subsequent treatment of the pulp depends on the kind of paper that is required. Papers may be roughly divided into two classes, viz., "tub-sized" and "engine-sized." As all papers, even tub-sized, excepting blotting- or water-leaf-paper, are more or less sized in the engine, this may form the next point for consideration.

Sizing.—The principle upon which engine-sizing depends is briefly this, viz. the precipitation and intimate mixture with the pulp of a substance which, when dry, will to some extent fill up the interstices between the fibres of the paper, and which possesses the property of being with difficulty wetted with water. Such a substance is the compound of common rosin with alumina. In order to obtain a thorough mixture of this body with the fibre, it is always formed in the engine by adding an aqueous solution of rosin-soap to the pulp, and when this is intimately mixed with it, running in a solution of alum. The rosin-soap is made in the following manner. Ordinary rosin, the quality depending on the quality of paper required, is boiled, preferably in a steam-jacketed boiler, with a solution of carbonate of soda (ordinary washing soda) until a sample of the soap formed is completely soluble in water. This takes place in about 2½ hours. The amount of carbonate of soda used differs widely, though why, it is difficult to see; usually about 1 part to 3 of rosin is considered necessary. Any excess above the quantity required to thoroughly dissolve the rosin is useless and wasteful, because, if left in the soap, it consumes an equivalent quantity of alum, and cannot possibly serve any good purpose. The boiling being completed, the charge is run off into iron tanks, and allowed to settle. The soap soon cools to a semi-solid mass, and a quantity of liquor, containing a considerable portion of the impurities, such as colouring matter, of the rosin, rises to the top, and can thus be removed. The soap so purified is next dissolved in water, with the addition of a small quantity of carbonate of soda, if necessitated by imperfect boiling in the previous operation, and is mixed with a quantity of starch-paste, made up in a separate vessel by dissolving farina in hot water. The mixture is then carefully sieved, and is ready for use. Some manufacturers prefer caustic soda for forming the soap, and others use soda ash; all are equally suitable. The proportion of starch to rosin differs in nearly every mill, and the quantity of size to be added to the beater varies according as the paper is required to be soft- or hard-sized. About 1½ parts of starch to 1 part of rosin is an average quantity; and about 3½ lb. of the mixture to 100 lb. of dry pulp is a fair proportion. In some mills, it is the practice to make up the starch with the China-clay, instead of mixing it with the rosin. (For Rosin, see Resinous Substances.)

It is better, but not absolutely necessary, to dissolve the size in water before putting into the engine. After allowing the rosin-soap and starch to get thoroughly mixed with the pulp, the alum solution may be run in. It is made up in a large leaden tank, furnished with steam-pipes for heating; it is necessary to use lead, as the alum in strong solution rapidly attacks iron vessels. The choice of a suitable alum is a matter of very great importance; care should be taken that it be free from excess of sulphuric acid, and from soluble iron. The sulphuric acid is deleterious on account of its action upon the colouring matter used subsequently, some colours being completely discharged by it, and because of its effect upon metal-work in contact with it, especially upon the brass wire-cloth on which the paper is made. As the sulphate of alumina is the only active agent in the alum, the sulphates of potash and ammonia being without any action on the rosin-soap, some paper-makers use a preparation called "aluminous cake," which consists entirely of sulphate of alumina. The only objection to this substance is that it not unfrequently contains an excess of free sulphuric acid and soluble iron. If it could be guaranteed free from these impurities, there is no reason why it should not supersede the more expensive alum. A considerable excess of alum over the quantity necessary for precipitating the rosin is employed, as it has the effect of brightening the colours added subsequently. Other materials have been suggested as substitutes for rosin in the sizing process, but none can compete with it in point of economy. Wax, dissolved in soda, and precipitated with alum, will answer the purpose, but it does not appear to have been used on a manufacturing scale. The addition to the rosin of a small proportion (about 2½ per cent.) of gum tragacanth is said to be very advantageous, giving the finished paper some of the characters of a tub sized paper. (For Alumina, see Mordants, pp. 1295–6.)

It is necessary at some stage of the treatment of the pulp in the beaters, and before the addition of the colouring materials, to add some substance that will entirely get rid of any bleaching-liquor unavoidably remaining in the pulp. The substance usually employed is sulphite of soda, technically known as "antichlor." Its action depends upon the fact that it is converted into sulphate of soda by the active chlorine in the bleaching-liquor, the latter being at the same time changed into a chloride, in which state it is quite inert. If any free chlorine were allowed to remain, it would be very hurtful, as it would bleach the pink employed, and would at the same time act injuriously on the wire-cloth. Other substances have been used instead of the sulphite of soda, almost any reducing agent being suitable. A very cheap substitute is often prepared by boiling sulphur with milk of lime. It is the practice in some mills to wash out the excess of bleach with water, the beaters being supplied with drums for this purpose.

Colouring.—The colouring matters usually added for the production of white paper are ultramarine and pink, the latter being either a preparation of cochineal or a coal-tar colour. Sometimes a coal-tar blue is used instead of ultramarine. The addition of a small quantity of blue and pink is requisite to complement the slight yellow colour of the pulp, and so produce a white paper. The ultramarine has to be chosen with special reference to its tinctorial power, and chiefly to its capacity for resisting the action of alum, inferior qualities being discharged by the latter. Ultramarine, being a pigment, is only mechanically held by the pulp; aniline blue actually dyes the pulp, and is therefore more intimately combined with it.

Paper of any colour may be made either by adding some material of the colour required, or such substances as will produce it. It will not be necessary to enumerate here the different materials employed. The so-called "toned" paper is produced by adding to the pulp a solution of pernitrate of iron, from which a fine precipitate of oxide of iron deposits on the fibres, and thus the slightly brownish shade is obtained. The size, clay, and colouring materials having been added to the pulp, nothing now remains but to reduce it to a sufficiently fine state of division. In this part of the process, much care and attention are called for, as upon the proper conduct of the beating operation, the character of the paper greatly depends.

The object of the beaterman should be, by carefully adjusting the distance of the roll from the bed-plate, to thoroughly disintegrate the esparto, and to produce a pulp with as long a fibre as possible. If the roll be lowered too much at the commencement of the operation, the fibres, instead of being drawn out or beaten, will be cut by the knives, and the paper will be proportionately weakened.

If circumstances allow of it, the pulp should be worked in the beaters for a long time, and the disintegrating process should be conducted slowly; but the method of working depends considerably upon the character of the paper required. Thus, if a very thin paper is to be produced, it is absolutely necessary, in order to make a strong firm sheet, to beat the pulp slowly, and preserve the fibre, whereas this is not so necessary in the case of thick papers. In this, as in many other particulars, the manufacturer has to consider not only the production of a good strong sheet of paper, but, on the other hand, the expense involved on account of the extra time and power consumed.

Though the ordinary form of beater contains only one roll, some have been made containing two, and with a special appliance for sending the pulp under the rolls in two separate streams. Engines have been made containing even four rolls. In some American mills, beating-engines are employed of a totally different construction from the ordinary form. The most important of these are the Jordan and Kingsland beaters, so called from the names of their inventors. The former consists essentially of a conical-shaped roll, studded with knives, in the same way as the ordinary roll, revolving in an iron box of corresponding shape, and fitted with knives placed at slightly different angles in the direction of its length. The half-stuff enters at the narrow end, through a box provided with an arrangement for regulating the flow, and is discharged through two or more openings in the cover at the wide end. The Kingsland engine consists of a vertical, circular chamber, the sides of which are covered with knives, and between which a circular plate revolves; this is also covered on both sides with knives. The pulp enters through a pipe in the centre of one of the sides of the chamber, and flows out through an opening in the opposite side.

The latest form of beater is that invented by S. L. Gould. The essential difference between it and the Kingsland is that, instead of having a plate revolving vertically against two stationary ones, its plate, which is placed horizontally, is covered with knives on one side only, and revolves upon but one fixed plate, much in the same way as a pair of mill stones.

The pulp supplied to these forms of beater is generally broken much finer than is the case with the ordinary kind, because it is necessary to make it flow easily through them; this could not be done if the fibres were not sufficiently broken up. The chief advantages claimed for them is that they are more economical, both of time and power; also that the pulp is more regularly beaten.

Treatment of Rags.—The first step in the treatment of rags is to remove, before sorting, as much as possible of the dust and other impurities which invariably accompany them. This is not absolutely necessary, though advantageous, as it renders them less unpleasant for the workers to sort subsequently. This preliminary purification is generally done in a machine, technically called a "thrasher." It consists essentially of a square wooden box, the top of which is lined inside with steel spikes about 6–8 in. long. The box is divided into two portions, by means of a piece of coarse wire gauze. In the upper portion, a shaft revolves, bearing a number of teeth, similar to, and alternating in position with, the stationary teeth at the top of the box. The rags are supplied at one end of the box, and are discharged at the other, the dust having escaped through the wire gauze into the bottom division. It is objected by some that the thrasher causes a great waste of fibre, but, on the other hand, it may be said that a less violent subsequent treatment is necessary.

Cutting.—The next thing to be done is to sort and cut the rags into convenient pieces. This work is usually performed by women, who stand at tables, each with a broad knife firmly fixed into it, and inclined at a slight angle, with its back towards the worker. Before the women, are placed wooden boxes, the bottoms of which are covered with coarse wire gauze, the number of the boxes being determined by the number of different qualities of rags desired. Each mill has its own particular method of working, but, as a general rule, the rags are sorted with special reference to their colour, and the material of which they are composed. They are generally cut into pieces of 2–5 in. square. In some places, machines are used for cutting the rags, but though useful for some kinds of paper, they can never supersede hand-cutting for the finer qualities. One chief reason is that with hand-cutting, the rags can be much more efficiently sorted, and imperfect pieces rejected. It is said also that machine-cut rags suffer greater loss of fibre in the treatment that follows than do those cut by hand.

Dusting.—The cut rags are generally passed through a "duster," in order to complete the removal of dust and dirt. The rag-duster is usually a round or octagonal box of wire gauze, strengthened with stays and ribs, revolving inside a wooden box, one end being slightly raised to facilitate the motion of the rags, which enter at the higher and are discharged at the lower end. Occasionally the wire box is made conical. Various forms of duster are used, but they differ only slightly in principle from the one described. If necessary, rags are put through more than one duster, and, in some places, they are put into a "devil" as well, where they are subjected to a much more violent treatment. The "devil," which is of a somewhat similar construction to a thrasher, is used only when the rags are exceptionally dirty. Some manufacturers pass the dust from the ordinary rag-duster through another made of finer gauze, in order to save the fibre which becomes detached. The loss occasioned by dusting and cutting differs as much as the material the rags are made of; it varies from 6 to 15 per cent.

Boiling.—The next process is that of boiling, though some paper-makers prefer to give the rags a preliminary washing.

The boiling may be accomplished in various kinds of vessels, either stationary or revolving, but the latter are very generally preferred, owing to the fact that a more perfect circulation of the liquor is obtained with them than with the former.

The revolving boilers may be either cylindrical with round ends, or spherical; if cylindrical, they are usually made to revolve horizontally. Some cylindrical boilers, however, are placed in an inclined position, and are fitted inside with a spiral band of thick iron, to facilitate the agitation of the rags. All revolving boilers are fitted with hollow journals, through one of which, enters the steam for boiling. The "chemical" used may be lime, carbonate of soda, caustic soda, or a mixture of the two former, which is of course equivalent to the latter. The quantities used, as well as the pressure, and time of boiling, vary with the character of the rags; as a general rule, it may be stated that rags require much weaker solutions than esparto and most other materials, as the grease and colouring matter are comparatively readily removed.

The boiling having been completed, the rags must be washed. This is sometimes partially accomplished in the boiler. The rags are taken from the boiler to the washer. This is similar in construction to that described under esparto. The breaking and washing usually occupy 2–4 hours.

Bleaching.—The bleaching of the rags may be conducted in a similar manner to that of esparto. In addition, the method of bleaching with gas, and sour-bleaching, are sometimes resorted to. The former, on account of the great inconvenience due to the escape of chlorine, is but rarely used. It may be conducted in large chambers made of brick and cement or stone, and with a tight-fitting top, connected by a stoneware pipe with the apparatus for generating the gas. This may conveniently consist of stoneware retorts or small tanks of stone, fitted with some arrangement whereby they can be heated. The chlorine is obtained by heating black oxide of manganese with hydrochloric (muriatic) acid, or a mixture of the oxide of manganese and salt with sulphuric acid. Sour-bleaching consists in the alternate treatment of the rags with bleaching-liquor and a weak acid. It is usually done in large chests or drainers. In some mills, the half-stuff is first well soaked with the bleaching-liquor, and then weak sulphuric or muriatic acid is run in upon them; in others, the reverse takes place, the acid being allowed to saturate the pulp first, and then the bleach is run in. The most economical way would appear to be, first to bleach as much as possible with liquor alone, and then to add an acid when this is nearly exhausted. Whatever the method of bleaching employed, the excess of bleaching agent must be got rid of, and this can be accomplished by one or other of the methods before described. The subsequent treatment of the pulp calls for no special remarks; the time necessary for reducing rags to the proper degree of fineness is, however, generally longer than for esparto.

Treatment of Straw.—The preparation of paper-pulp from straw has been the subject of numerous patents, chiefly in France and America. They do not, however, differ from each other to any great extent in principle.

Cutting.—The first process to which straw is subjected is that of cutting. This is done principally for the purpose of rendering it more convenient to pack into the boilers; it also makes it more easily cleaned. The cutter is similar to that ordinarily used for cutting hay for stable uses. The cut straw has to be cleaned and freed from the dust and dirt that invariably accompany it. This operation may be performed in various ways. One very suitable method is to blow the straw by means of a violent blast of air along a wooden tube or shaft, into a chamber, whose sides are made of coarse wire gauze, through which the dirt escapes. The straw thus purified is taken to the boilers.

Boiling.—The boilers are usually rotary, and closely similar to those used for rags. The heat may be applied in several ways: directly; by means of a steam-jet opening into the boiler; or by means of a coil of steam-pipe. The direct method is but seldom used, as it sometimes entails damage to the pulp, through overheating due to imperfect circulation. This cannot happen with the two latter arrangements. The objection to heating by means of an open steam-pipe is that the liquors are unduly diluted by the condensed steam, and, for this reason, the last-mentioned plan is preferred by some. A solution of caustic soda is the agent invariably used, the strength necessary depending very largely on circumstances, such as the pressure, and time of boiling. A higher pressure than that required for esparto and rags is necessary, 60–80 lb. a sq. in. being usual. The time may vary from 6 to 12 hours, and the amount of caustic soda from 15 to 25 lb. a cwt. Some manufacturers recommend a preliminary boiling in water; this has the effect of removing a large quantity of matter from the straw, and of rendering the subsequent boiling process easier. The washing may be performed in large vats provided with perforated bottoms, or in an ordinary washing-engine, in which latter case, the roll should carry only blunt knives, as the fibres are generally sufficiently disintegrated by the boiling process. When properly washed, the pulp may be bleached by one of the ordinary methods. When this is accomplished, antichlor is put in to remove the excess of bleach, and the pulp, which is much too finely divided to allow of its being pressed, is made into a coarse thick web of paper; by this means, most of the lime and other substances from the bleach are got rid of. The machine on which this is done corresponds exactly to a paper-making machine proper, without the drying-cylinders and calenders. This method may also be adopted before bleaching, in order to get rid of the last traces of the liquor from the boiling operation, and free the pulp from knots, sand, &c., the machine being provided for this purpose with sand-tables. The pulp, in the form of rolls or webs of thick paper, is ready to be taken to the beaters, where its subsequent treatment is similar to that of other fibres. Owing to the fact just mentioned, that the straw is to a considerable extent disintegrated by the boiling process, very little working in the beaters is sufficient. In other establishments, the straw is drained in large stone chests, similarly to esparto and rags.

Treatment of Wood.—The manufacture of paper-pulp from wood is confined almost exclusively to Sweden and America. This appears to be due to the fact that, in these countries, abundance of suitable wood is found, and can be very cheaply obtained. Many attempts have been made in this country, but they have been nearly all abandoned. In America, poplar is the wood generally employed, on account of the ease with which it can be disintegrated.

The method of treating it is as follows. The wood is brought to the mills in cords of about 5 ft. long. The bark is removed, and the blocks are cut into thin slices across the grain, in a machine constructed somewhat on the principle of an ordinary chaff-cutter. The wood is passed slowly and steadily, by means of an advancing screw, along a trough, at the end of which it comes against very strong steel knives, firmly fixed on a rapidly-revolving cast-iron disc.

Boiling.—The slices of wood, which are about ½ in. thick, are then taken to the boilers. These are vertical cylinders, about 5 ft. in diameter and 16 ft. high, divided into compartments by means of perforated diaphragms. The boilers are heated either directly by means of furnaces underneath, or by steam circulating round an outer jacket. The boilers are partially filled with a solution of caustic soda at about 17° Tw., and the heat is kept up for 6 hours, the pressure being equal to about 70 lb. a sq. in. At the end of this time, the contents of the boiler are ejected with considerable violence into a large iron chamber placed underneath (see Bamboo and Cane, p. 1485). The pulp is then allowed to pass into large iron drainers, mounted on wheels for convenience of locomotion. In the centre of the tramway along which the drainers pass, are placed sewers to receive the liquor. When as much as possible of the liquor has drained away, hot water is poured upon the pulp. A small quantity only is used, so as to keep the liquor sufficiently concentrated to pay for evaporation. The pulp is then taken to washing-engines, similar in principle to those described under Esparto, p. 1487. The washed fibre is next freed from unboiled portions, sand, &c., by being passed over sand-tables and through screens (see Paper-machine, p. 1494), and is then passed over the wet end of a machine, as in the case of straw. It is bleached in the ordinary way, and is then made into a very thick coarse web on a cylinder paper-machine; in this form, it is sold to the paper-manufacturers. The subsequent treatment of it in the paper-mill calls for no special remarks. Wood-pulp so prepared may be used alone, or mixed with rags or other material, for almost all classes of paper.

The fibres prepared from poplar are very white, but are somewhat deficient in strength; those from other woods, such as members of the family of *Coniferæ* (pines), are much longer and stronger, but owing to the fact that, in the raw state, they usually contain a very large quantity of resinous matter, these woods are much more difficult to digest, requiring a stronger solution of caustic soda, and a considerably higher pressure. The process just described is that actually in use at a mill in America; at other places, a similar method of treatment is adopted, or if any material difference exists, the details are kept secret. Many other reagents have been suggested as substitutes for caustic soda. Among these, may be mentioned sulphide of sodium, chlorine, and a mixture of hydrochloric and nitric acids (aqua regia). But, as far as is known, they have all been abandoned, on account of the expense and extra trouble involved in their use. Many attempts have been made to utilize the fibre in sawdust, by treating it with one or other of the before-mentioned chemicals, but hitherto without much success. Works have also been erected in this country with a view of obtaining pulp from other waste forms of wood, such as small chips and shavings; but, principally owing to the nature of the material, and the consequently severe treatment necessary for their disintegration, they too have been given up.

The so-called "mechanical" wood-pulp is obtained by disintegrating the wood entirely by means of machinery, without the use of chemicals. As long as 100 years ago, it was proposed to utilize sawdust and shavings, by stamping them into a pulp; but owing to the want of suitable machinery, the attempt was unsuccessful. The next idea was to disintegrate blocks of wood, by grinding with rapidly-revolving cylinders of stone. This, after many years of labour, has been brought to a state in which it is a commercial success. The details of the process are as follows:—The wood is first cut up into blocks, the size of which is determined by the width of the stones used for grinding; any knots present are cut out with an axe. The stones are made of sandstone, and are covered over three quadrants with an iron casing, the remaining quadrant being exposed. The surfaces of the stones are made rough by the pressure of a steel roll studded with points, and which is pressed against it while revolving. In addition to this, channels, about ¼ in. deep are cut into the stone at distances of 2–3 in. They are made in two sets, crossing each other in the centre of the stone, and serve to carry off the pulp to the sides of the stone, in addition to giving increased grinding-surface. The pressure of the blocks of wood against the stones is steadily maintained by screws worked by suitable gearing; this is necessary in order to obtain a pulp of uniform character. A stream of water is kept constantly playing on the stone; by this means, the pulp as formed can be conveniently carried away. It is first passed through a rake, which retains small pieces of wood that have escaped grinding. The stream of pulp then passes through the sorters. These are cylinders about 3 ft. long and 2 ft. in diameter, covered with a coarse wire-cloth (No. 18). The fibres that are retained by this wire fall into the refiners, which consist of a couple of horizontal cylinders of sandstone, the upper one only of which revolves. Here they are further disintegrated, and are again passed through the wire-cloth; this is repeated until all the fibres have passed through. The pulp, after passing through the first sorter, may be conducted through a series of gradually increasing fineness, and, by this means, be separated into different qualities. Though pulp so prepared cannot compete with chemically-prepared stuff, as the fibres are extremely short, and have comparatively little felting-power, it may be used with advantage as a sort of filling-material. It is said to be used entirely for some low-quality newspapers.

Various modifications of the foregoing process have from time to time been proposed; among others, that of softening the wood by previous soaking in water, or steaming, seems to be valuable, as by so doing, it is highly probable that a longer fibre could be obtained, the soft wood being more readily torn away by the stones. Some inventors have proposed to replace the sandstone by an artificial stone containing a large quantity of emery.

Treatment of "Broke" Paper.—As "broke" paper has already passed through the manufacturing process, but little is necessary to be done to it. If quite clean, it only requires to be broken up again in an engine; but if dirty, or with much printing on it, some sort of boiling is necessary. Generally speaking, a rather dilute solution of soda is sufficient. Sometimes it is necessary to thrash and dust the waste paper much in the same way as rags.

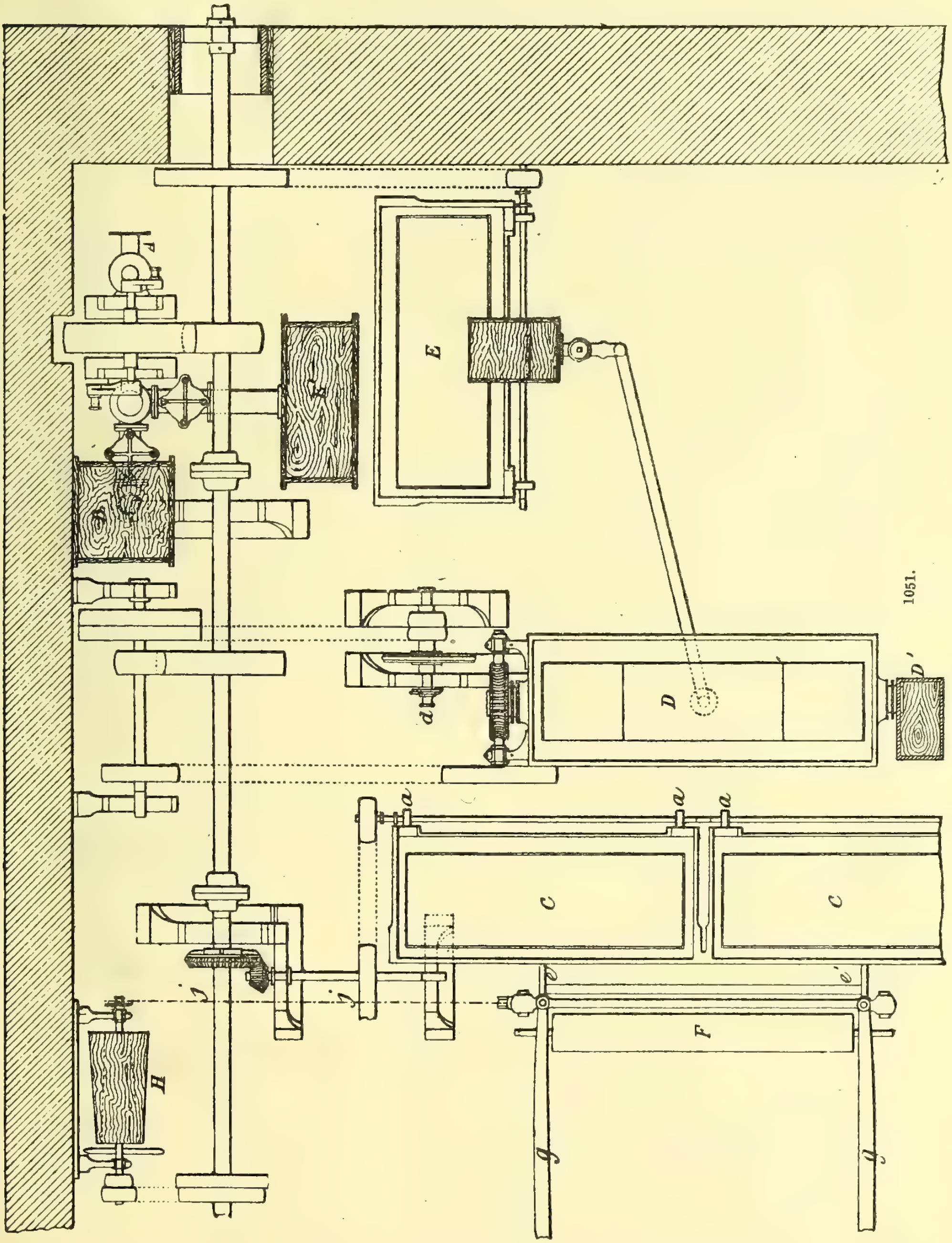
Hand-made Paper.—The preparation of the pulp for hand-made is similar to that for machine-made paper. Generally speaking, however, paper can only be made successfully by hand, when long and strong fibres are used; with short and inferior pulp, it is difficult to form a continuous sheet of any size. Hence hand-made papers are almost exclusively manufactured from pulp prepared from rags, or some such strong material.

A very brief description of the actual process will be sufficient, and it will at the same time facilitate the right comprehension of the machine process. The paper is made on a mould of wire-cloth, with a movable edge of wood, extending slightly above the surface of the mould, called the "deckle." The wire-cloth is generally supported by pieces of thick wire placed beneath it, and these again by wedge-shaped pieces of wood, the thin end being next the wires. To form a sheet of paper, the workman dips the frame into a vat containing the prepared pulp, lifting up just so much as will make a sheet of the necessary thickness. As soon as the mould is removed from the vat, the water begins to drain through the wire-cloth, and to leave the fibres on the surface in the form of a coherent sheet, the felting or intertwining being assisted by lateral motion given to the frame by the workman. The movable deckle is then taken off, and the mould is given to another workman, called the "coucher," who turns it over and presses it against a felt, by this means transferring the sheet from the wire to the felt. A number of the sheets thus formed are piled above each other, alternately with pieces of felt, and the whole is subjected to strong pressure, to expel the water. The felts are then removed, and the sheets are again pressed. After this, they are sized by being dipped in a solution of gelatine; again slightly pressed, and then hung up separately on lines or poles to dry.

The making of paper by hand is comparatively little practised in the present day; some kinds of paper, however, such as bank-notes, and different kinds of drawing-paper, are always made in this way.

Any pattern or name required on the paper is obtained by making the wire-cloth mould in such a way that it is slightly raised in those parts where the pattern is needed; consequently less pulp lodges there, and the paper is proportionately thinner, thus showing the exact counterpart of the pattern on the mould. Such are known as "water-marks."

The Paper Machine.—The pulp, after leaving the beaters, passes into a large vessel called the stuff-chest, of which there are one or more to each machine. As soon as the beater is empty, water is run in to thoroughly rinse out the remaining pulp, the washings also going into the stuff-chest. These may be made either of wood or iron, and should be provided with arms fixed on a vertical shaft, made to revolve by suitable gearing. The arms are for the purpose of keeping the pulp thoroughly mixed, and should only work at a moderate speed, otherwise they would be liable to cause the fibres to go into small knots or lumps. The pulp is drawn from the stuff-chests by means of the pump A (Fig. 1051), and is discharged into a regulating-box (not shown). The object of this box is to keep a regular and constant supply of pulp on the machine. It consists of a cylindrical vessel, having two overflow-pipes near the top, and a discharge-pipe near the bottom. The pulp is pumped in through a ball-valve in the bottom, in larger quantity than is actually needed, the excess flowing away back into the stuff-chests, through the two overflow-pipes. By this means, the box is always kept full, and therefore the stream of pulp issuing out of the bottom pipe is always under the same pressure. It flows from this pipe, the quantity being regulated by means of a cock, according to the thickness of paper required, directly on to the sand-tables. These may be of various sizes and shapes, but should be so large that the pulp takes some little time to travel over them. They consist of long shallow troughs, generally of a sinuous form. The bottoms are partly covered with woollen felt, having very long hairs on its surface, and partly with thin strips of wood placed across the direction of the flow of the pulp, and at a slight angle. They and the woollen felt serve the purpose of retaining any particles, such as sand and dirt, that may have escaped removal in the previous treatment of the pulp, and that are heavy enough to have



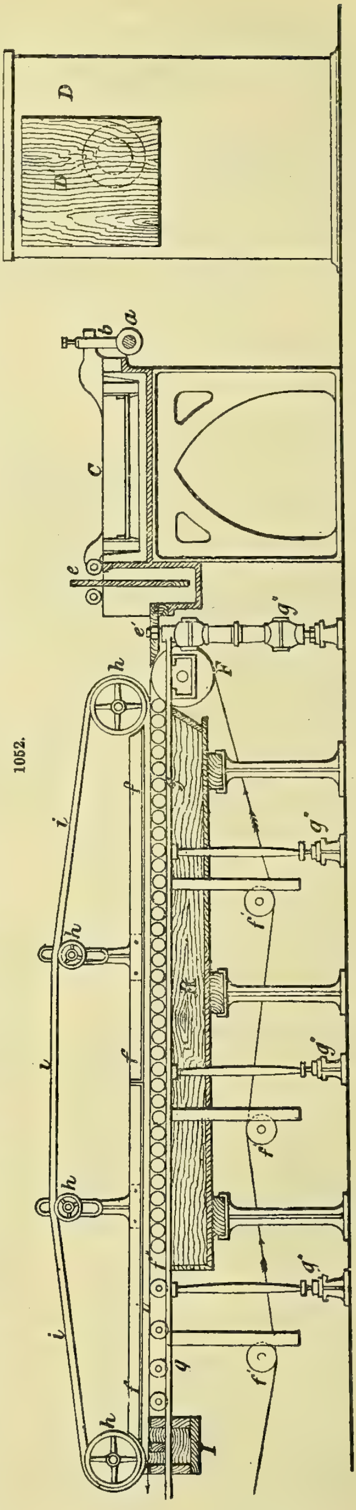
1051.

sunk down during the passage of the pulp over them. As the pulp, when it leaves the stuff-chests, does not contain sufficient water for the purpose of making paper, it is mixed, at the end of the sand-tables where it flows on, with a quantity of water from the "save-all" (see farther on), flowing from the box B (Fig. 1051) placed at a higher level.

Instead of being pumped into the regulating-box, in some mills, the pulp flows into a small vessel below the stuff-chest, and is lifted on to the sand-tables by means of buckets fastened on the circumference of a wheel.

The pulp, after leaving the sand-tables, passes on to the strainers. These consist of strong brass or composition plates, having a large number of very fine V-shaped slits cut in them, the narrowest end being on the outside.

The strainers are for the purpose of removing from the pulp all lumps formed by the intertwining of the fibres, and all pieces of unboiled fibre, which, if allowed to pass on, would show in the paper as inequalities in the surface, or as dark specks. The slits are made narrow at the top, and gradually increasing in width, so as to prevent them from getting choked up. These slits allow only the separated individual fibres to pass through, and their width varies according to the quality of the paper. They are put at distances of about ¼ in. apart. Several plates, each containing about 500 slits, are bolted together, and form a strainer. The whole strainer receives a violent shaking motion, to assist the passage of the fibres through the slits. In the machine represented, two of these strainers are shown at C (Figs. 1051 and 1052). The shaking motion is produced by the ratchet-wheel or cams *a* acting on the hammer *b* (Fig. 1052). An improved form, called the "revolving strainer," has of late years been introduced, and is often used in addition to the ordinary ones. The pulp generally passes first through one of these, and then through the ordinary or "flat" strainers, as they are called. A revolving strainer is shown at D (Figs. 1051 and 1052). It consists of a rectangular box, the sides of which are plates perforated with slits. Inside this box, a slight vacuum is formed by means of an indiarubber bellows worked by the crank *d* (Fig. 1051). The vacuum is intended to serve the purpose of the shake in the ordinary form. The box revolves slowly inside a vat containing the pulp, and the strained pulp flows into the box D¹ (Figs. 1051 and 1052), and thence on to the flat strainers. Various patents have been taken out from time to time for flat strainers worked by means of a vacuum underneath the plates caused by the motion of discs of indiarubber or thin metal. The same principle has also been applied to the revolving strainers. After a time, the slits in the plates get too large, owing to the plate having been worn away by the constant friction of the fibres, and as they are very expensive, various attempts have been made to invent plans for partially closing them again. Hammering will effect this, but it is liable to break the plates. Annandale of Beltonford has introduced a method of closing the plates, by means of heavy pressure acting on small steel rollers moving on each side of the slit, in which is placed a small sheet of metal the exact thickness of the width desired. The knots and impurities which collect on the outsides of the strainers must be from time to time removed, otherwise the slits would get choked up. In the case of revolving strainers, all that cannot pass through the slits falls to the bottom of the vat, in connection with which it is the custom now to have an auxiliary strainer, or "patent knotter," as it is called, shown at E (Fig. 1051). All fibre that passes through this one, which is of the ordinary flat kind with shaking motion, goes into a box near E′ (Fig. 1051), called the "low box" for "save-all" water (see farther on).


1052.

The pulp, after passing through the strainers, should be perfectly free from knots and impurities, and in a fit condition for making paper. In the machine shown, it passes from the last strainer directly on to the wire, its flow being regulated by a movable gate *e* (Fig. 1052). In some cases, however, it first flows into a small vat, in the centre of which revolves a rod carrying paddles, with the object of keeping the pulp well stirred up. It is carried right on to the wire by means of the apron, a piece of canvas, oil-cloth, or sheet rubber, one end of which is fastened to the breast-board *e′* (Figs. 1051 and 1052), the other end resting on, and covering, the wire to the extent of about 15 in. The edges of the apron are rolled up to prevent the pulp from overflowing. After leaving the apron, it passes under a gate, or "slicer," as it is sometimes called, made of two pieces of brass, overlapping each other in the centre, and bolted together. It is made thus to enable it to be lengthened or shortened according to the width of the paper; its height from the wire-cloth can be altered by means of screws, and should be equal at all points, in order to ensure a uniformly thick sheet of paper. The ends of the two pieces forming the slicer are fastened to the frame *f* (Fig. 1052), or "deckle," as it is called, and this again is carried by two or more rods stretching right across the wire, and fastened by small upright supports on both sides to the frame *g* (Figs. 1051 and 1052). The deckle-frame also carries the grooved pulleys *h* (Fig. 1052), along which the deckle-straps *i*, endless square bands of indiarubber, move. The deckle-straps rest on the wire, and move with it, the width of the paper depending on their position, which can be altered by shifting the deckle-frame along the rods mentioned.

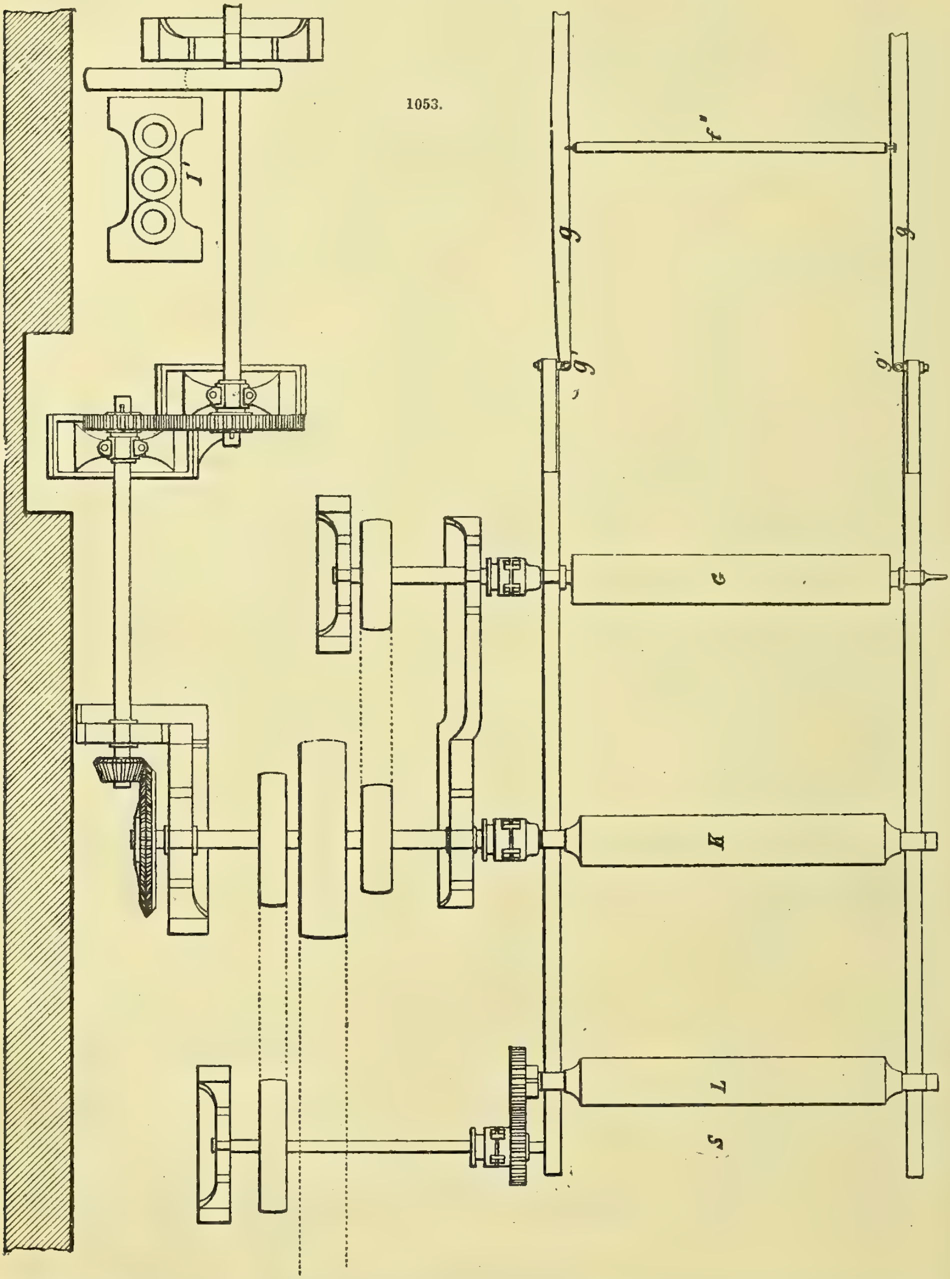
The "wire" is an endless cloth made of very fine wire, the fineness depending much on the quality of the paper required. The mesh varies from 60 to 70 and even more threads to the inch. It is not woven endless, but is joined by very careful sewing, with wire. Its width varies considerably, that on the machine shown being 76 in.; the length is generally 35–40 ft. It is carried by the breast-roll F (Figs. 1051 and 1052), the lower couch-roll G, and the small rolls *f* (Figs. 1052 and 1053), and by a large number of small rolls *f″*. The latter and the breast-roll are supported by the frame *g*, while the small rolls *f′* are supported by brackets attached to it. The course of the wire is indicated by the arrows. The frame *g* works on two pivots *g′* (Fig. 1053), and receives a shaking motion from side to side from the rod *j* (Fig. 1051), in connection with a crank worked by two conical drums H (Fig. 1051). The supports *g″* are also pivoted at their lower ends to allow for the shaking motion. This shaking motion is given for the purpose of weaving or intertwining the fibres. One or more of the rolls *f′* can be moved up or down on the support which carries it, for the purpose of stretching the wire. There is usually a large number of the small rolls *f″*, as it has been found by experience that, probably owing to capillary attraction, they assist the water to leave the pulp. Though a large quantity of water thus passes through the wire-cloth, it is necessary to assist it by artificial means. This is done by means of the suction-boxes I (Figs. 1052 and 1054) connected by pipes with the vacuum-pumps I′ (Fig. 1053).

Underneath the wire-cloth, is placed a box called the "save-all" K (Fig. 1052), connected with the box E (Fig. 1051). The water that flows in here contains a considerable quantity of very fine fibres, together with size, alum, clay, and colouring materials, that have passed through the wire, and which would be lost but for the arrangement now universally adopted. It flows into the box E′, and is pumped, together with the pulp that has passed through the knotter E (see before) into the high box B, whence the mixed stuff flows on the sand-tables, to be again used to dilute fresh pulp from the stuff-chests. If any pattern or name is desired on the paper, it is done by means of a light skeleton roll, called a "dandy-roll," covered with wires in the form of the desired pattern, placed between the suction-boxes, and pressing lightly on the still moist paper. The paper is thinned where the wire pattern presses, and thus a mark (water-mark) is produced. The other side of the paper has a mark corresponding to the wire-cloth; by using a dandy-roll covered with wire-cloth, the two sides can be obtained alike, such paper going by the name of "wove."

It sometimes happens that the wire-cloth slips slightly to one side. This can be obviated by the machine-man shifting, by means of screws, one of the rolls provided for the purpose with a movable journal, until its axis is at a slight angle to that of the other rolls. An automatic apparatus has been invented for the purpose. Two brass plates are fixed, one on each side of the wire-cloth, to a long rod, connected by suitable machinery with the screws working the movable journal, so that, as the wire presses against one or the other of these plates, the roll is shifted so as to correct this.

The paper, which, even after passing the suction-boxes, is still very wet, passes with the wire-cloth between the couch-rolls G G′. (Figs. 1053 and 1054). These are hollow copper or brass cylinders, covered with a tightly-fitting endless jacket of felt. The pressure of the upper couch-roll upon the lower can be regulated by means of screws or levers. They serve to press out water from the paper, and to detach the paper from the wire-cloth. By dextrous manipulation on the part of the machine-men, the paper is transferred to the endless felt, travelling over the rolls *k* in the direction of the arrows. It is known as the "wet felt," from the condition of the paper at this stage. In its passage along this felt, the paper goes between two iron rolls K, called the first press-rolls, with the object of having the water squeezed or pressed out of it. These rolls are sometimes covered with a thin brass case, and the top one is provided with an arrangement called the "doctor," in order to keep it clean, and free from pieces of paper that may have stuck to it. The "doctor" is a kind of knife placed along the whole length of the roll, and pressing against it at every point.

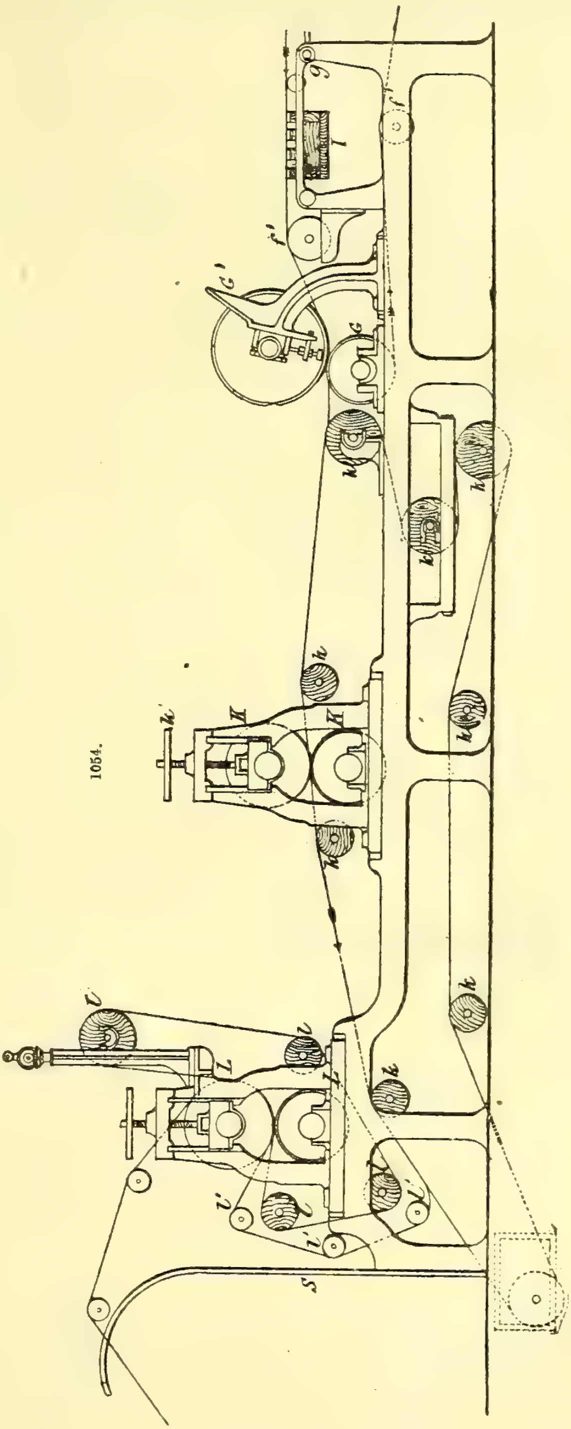
1053.



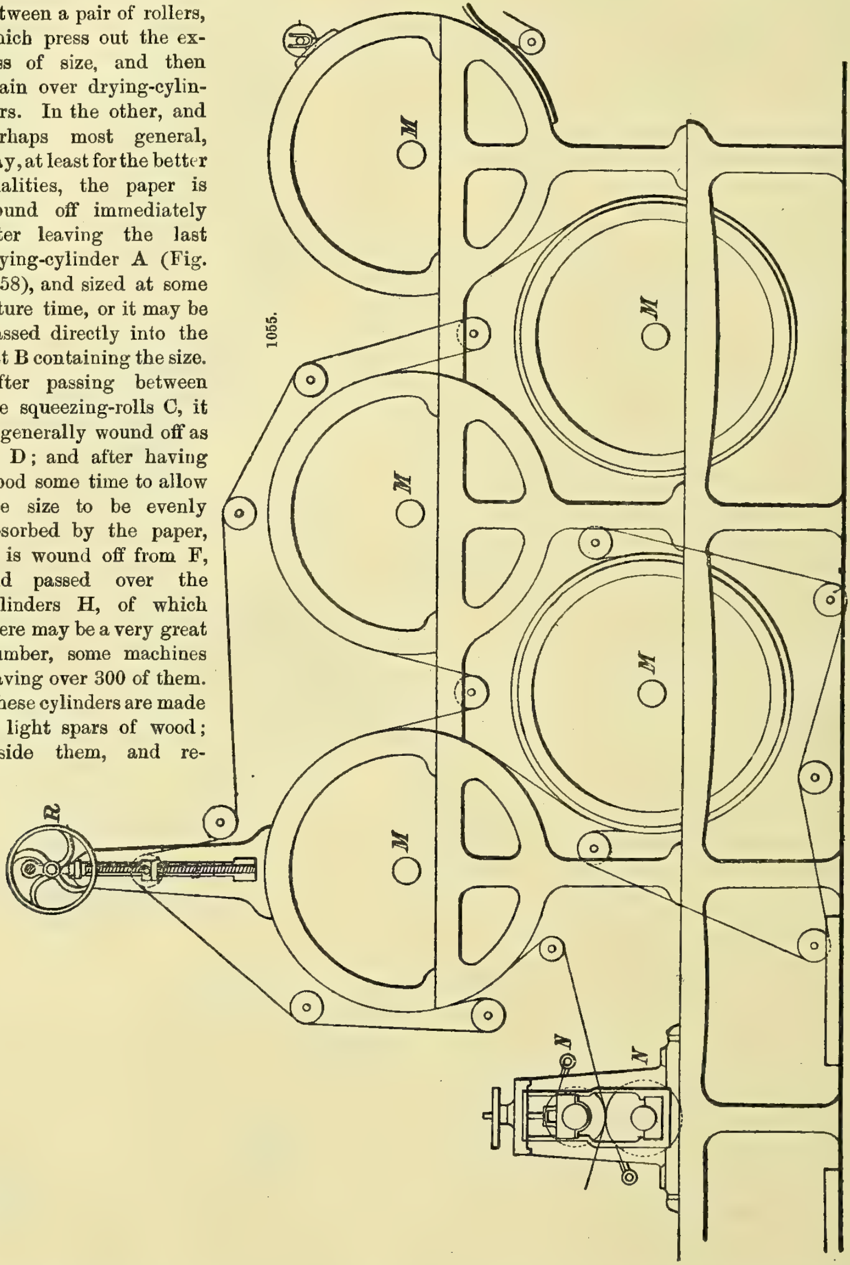
The pressure on the rolls can be regulated by means of levers, or, as in the illustration, by the screw *k'* (Fig. 1054). It will be readily seen that the under side of the paper that has been next to the felt will, in its still moist condition, have taken to some extent an impression from the felt, while the upper side will have been made comparatively smooth by the pressure against the top roll of the 1st press. In order to make both sides of the paper as nearly as possible alike, it is passed through another set of rolls L, called the 2nd press. This time it is reversed, and enters at the back of the rolls; thus the other side of the paper is next the metal, being taken through by the felt (called the "2nd press felt") travelling on the small rolls *l* (Fig. 1054), the paper, after leaving the wet felt, and before being taken on to the 2nd press felt, travels over the rolls *l'*. The 2nd press felt is necessary, because the paper in its then condition is too tender to withstand unsupported the pressure of the rolls.

The paper, after passing the 2nd press rolls, travels over the drying-cylinders M (Figs. 1055–6–7), the number of which varies somewhat. In the machine shown, there are in all eight cylinders. Between the 2nd press rolls and the cylinders, a passage S allows easy access to the other side of the machine. The paper generally passes over the first two, which are only slightly heated, alone; afterwards it is led over the others by means of felts, as shown. The arrangements shown at R (Figs. 1055–6) are for the purpose of stretching the felts. The cylinders are all heated by means of steam, and are generally divided into two sets, between which, is a pair of chilled-iron, highly-polished rolls N, called "smoothers," the function of which is sufficiently explained by their name. They are also heated by means of steam. The cylinders are usually made of slightly decreasing diameter, in order to allow for the shrinking of the paper on drying. After leaving the cylinders, the paper should be quite dry; it is then led through the calenders, of which there are in some machines as many as three sets, though only one is shown. These are similar to the smoothing-rolls, just described. Pressure is applied by the screws O′ (Fig. 1056), or by levers and weights. The friction of the hot calenders on the dry paper develops a large quantity of electricity, which discharges itself in bright sparks.

The finished paper, after passing through the calenders, is wound on the reels P. The gearing by which the whole machine is driven is shown in Figs. 1053, 1057.


1054.

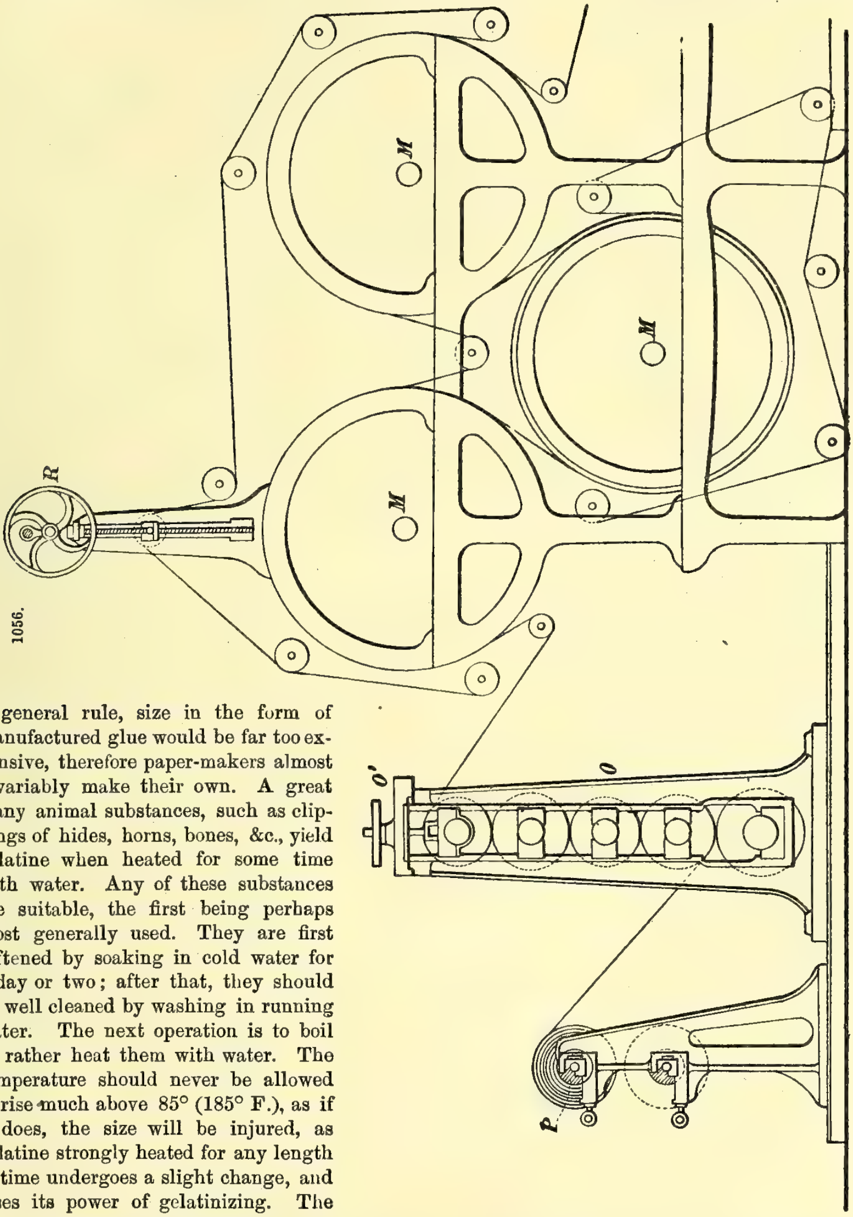
Tub-sizing.—The foregoing description is of a machine for the manufacture of engine-sized papers; some slight modifications are necessary in the case of tub-sized papers. One method, usually applied to the cheaper qualities of tub-sized papers, is to pass the paper, after being partially dried over a few cylinders, through a vessel containing a solution of gelatine or glue (see farther on). It then goes between a pair of rollers, which press out the excess of size, and then again over drying-cylinders. In the other, and perhaps most general, way, at least for the better qualities, the paper is wound off immediately after leaving the last drying-cylinder A (Fig. 1058), and sized at some future time, or it may be passed directly into the vat B containing the size. After passing between the squeezing-rolls C, it is generally wound off as at D; and after having stood some time to allow the size to be evenly absorbed by the paper, it is wound off from F, and passed over the cylinders H, of which there may be a very great number, some machines having over 300 of them. These cylinders are made of light spars of wood; inside them, and revolving rapidly in an opposite direction, are the fans G. The paper, in travelling over these drums, is only slowly dried, and is supposed by this means to be more perfectly sized, and increased in strength. It is wound on to reels again at I. Only the first and last two drums are shown. This method was devised to imitate, as far as possible, the sizing process of hand-made paper. Even now, paper that has been made on the machine is sized by hand, after having been cut into sheets, much in the same way as hand-made. The sheets are sometimes passed between



1055.

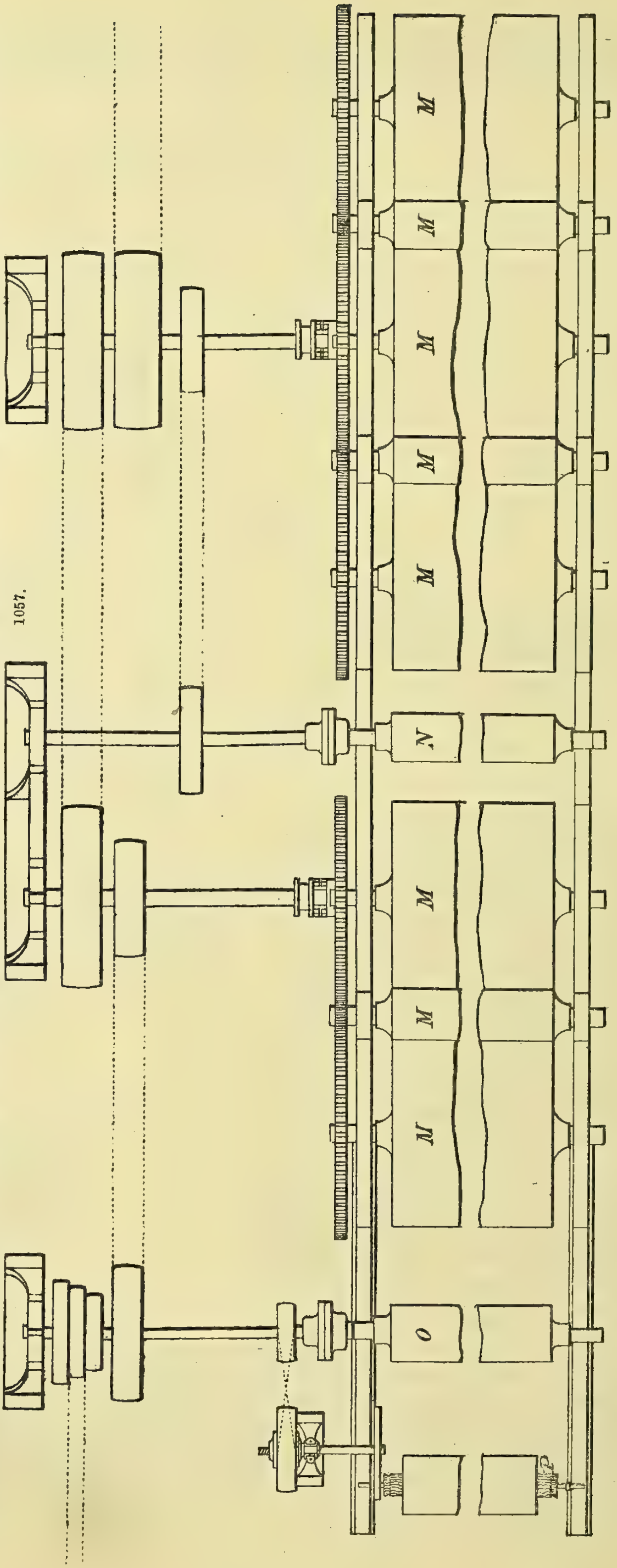
two endless felts dipping into a bath containing the solution of gelatine, the excess of size being squeezed out by the pressure of rolls on the felts. Such paper is dried on sticks in a large room kept at a temperature of about 21° (70° F.), and is called "loft dried" on this account.

The gelatine used for tub-sizing is made up somewhat after the following manner. As a general rule, size in the form of manufactured glue would be far too expensive, therefore paper-makers almost invariably make their own. A great many animal substances, such as clippings of hides, horns, bones, &c., yield gelatine when heated for some time with water. Any of these substances are suitable, the first being perhaps most generally used. They are first softened by soaking in cold water for a day or two; after that, they should be well cleaned by washing in running water. The next operation is to boil or rather heat them with water. The temperature should never be allowed to rise much above 85° (185° F.), as if it does, the size will be injured, as gelatine strongly heated for any length of time undergoes a slight change, and loses its power of gelatinizing. The operation should be conducted in an iron or copper vessel, provided with a false bottom, or a casing outside, where steam may be introduced, and it should extend over about 15 hours. The solution should then be drawn off, and filtered into some convenient receptacle. The residue can be again heated with water, and a fresh quantity obtained, which may be added to the bulk. A quantity of alum (about 20 per cent. of the clippings) dissolved in water, is added. The alum is necessary to prevent the decomposition of the gelatine, and to assist in the sizing process, as it helps to give hardness to the paper. After the addition of the alum, the size should be well filtered through woollen felt, after which, it requires no further treatment.


1056.

The paper-making machine before described is known as the "Fourdinier," from the names of the original inventors. Modified forms of this machine have been introduced to meet various requirements. One, suitable for the manufacture of very thin papers, resembles the ordinary machine as far as the couch-rolls. The paper is taken off the wire-cloth on to a long endless felt, running round the upper couch-roll, and extending in a slanting direction over the wire-cloth. It is taken off from this felt on to a large cylinder, about 10 ft. in diameter, heated by steam, and placed above the wire-cloth. After passing round nearly the whole circumference of this cylinder, the paper is sufficiently dry, and is then wound on to reels.

A machine of a very different construction from the ordinary form is shown in Fig. 1059. The pulp, after passing through the strainer A, enters the vat B, in the centre of which, revolves a large drum or cylinder C. This cylinder is covered with fine wire-cloth, and on it the paper is made. As it revolves, the fibres attach themselves to the wire, and the water passes through the meshes, the latter being assisted by means of a pump. The sheet of paper thus formed is taken on to the endless felt on the couch-roll D, and travels along with it to the large drying-cylinder E, heated by steam. It leaves the felt at F, and is then taken on to the cylinder, after travelling round which, it is sufficiently dried, and is then wound off as at G. The felt, on its return journey, passes through the washer H, where it is cleaned, and freed from adhering particles, by the scraper I. It is squeezed free from excess of water by the rolls K. Paper made on such a machine is



1057.

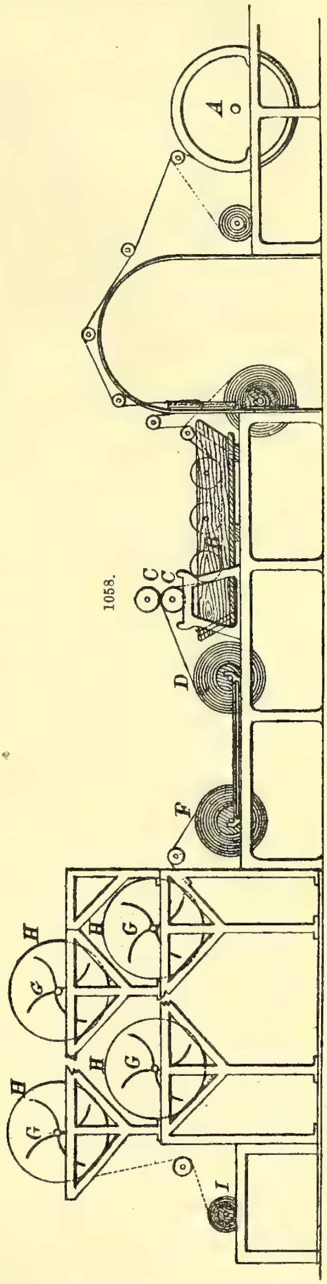
weaker than that made in the ordinary way, because it has not been found possible to give a shaking motion to the cylinder, and thus the fibres are not woven or intertwined.

A modification of this machine is used for making mill-boards, the difference being that it has no drying-cylinder. The felt carrying the paper passes between a pair of press-rolls, which squeeze out the water. The sheet of paper is then allowed to wind round the top press-roll until of the required thickness. When this happens, it is cut off the roll by a knife. The thick sheets so produced are dried, either in the open air, or in a room heated for the purpose.

Glazing.—For many purposes, the paper as finished on the machine, does not possess a sufficiently high surface. This may be increased in several ways. One method, called "web glazing," is to pass the paper between a number of rolls, alternately of polished iron and very highly-compressed paper. The construction of such a calender will be understood by reference to Figs. 1060 (end elevation) and 1061 (front elevation). The reel of paper, as taken from the machine, is shown at A (Fig. 1060), its course over the rolls being indicated by arrows. After passing over the bottom roll, it is wound off on a wooden or hollow-iron cylinder B (Fig. 1060), driven by the toothed-wheel shown by the dotted line C, on the same shaft as the wheel D, which is driven by E, keyed upon the bottom roll. The whole machinery is driven by the large toothed-wheel F (Figs. 1060–1), which is itself driven by the small wheel G (Fig. 1060) on the main shaft H. The paper rolls are marked P, and the iron rolls I. It will be seen that there are two paper rolls in the middle, for the purpose of, as it were, reversing the paper, and so making both sides alike. Pressure is applied to the rolls by means of the screws, and by the weight L (Fig. 1060) acting on the compound lever M. The brake, which consists of a strap of leather pressing, by means of the weight and lever N, on the circumference of the wheel O, connected by toothed-wheels with the cylinder on which the paper is wound, is used for the purpose of preventing the paper from leaving the wheel too rapidly. But for this appliance, the paper would be apt to crease. The paper rolls have an inner core of iron, the paper only extending to a depth of about 5 in. The iron rolls are hollow, and are connected with steam-pipes, by which they can be heated.

Another method, known as "friction-glazing," employed for giving a very high finish to paper, is to pass it between a large paper roll and a smaller iron one, the latter revolving at a much greater speed than the former. By this means, a very bright surface can be obtained. It is sometimes assisted by rubbing a small quantity of bees'-wax on the small iron roll. Plate-glazing, a method that is adopted for hand-made and the better qualities of paper, consists in applying heavy pressure to sheets placed between polished plates of copper or zinc. The metallic plates and the sheets of paper are made into bundles, and the whole is passed between two strong rollers, heavy pressure being communicated to them by means of screws or levers and weights applied to the ends of the top roller.

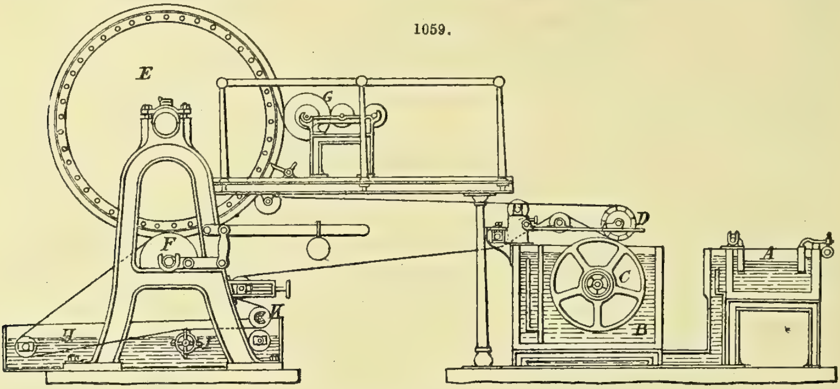
By passing paper between rolls on which devices have been cut or turned, the "repped" and other similar papers are produced.



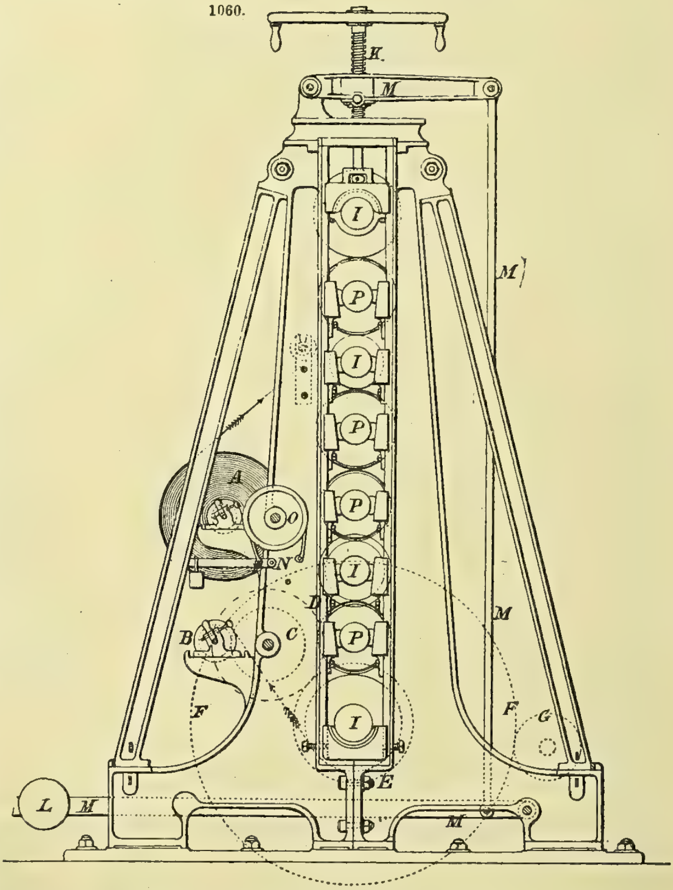
1058.

Cutting.—Except for special purposes, paper is usually sent from the mill in the form of sheets. The form of cutter generally used is shown in Fig. 1062. The paper from the webs A is drawn forward by the rolls B; it is then ripped into widths of a convenient size by means of two circular knives, the upper one of which is shown at C. It again passes between a pair of rollers, after leaving which, it meets a knife D fastened to the revolving drum E, and pressing against a fixed knife not shown. The cut sheets then fall upon the endless travelling felt F. The action of the knives will be understood by reference to Fig. 1063. The edges of the two knives are shown at A and B. The knife B has a slot, in which the bolt O slides, and it is kept in position by means of a spring. This spring causes the knife to slide back slightly as it comes against the fixed knife A. The position of the paper is shown by the dotted line C. The knife B is set on the drum not quite horizontally, so that one end meets the stationary knife a little before the other, thus acting in every respect like a pair of scissors. Fig. 1064 shows a pair of ripping-knives. The upper one A is kept in position against the lower one B by means of the spring C. The cutting surfaces are slightly hollowed out, so as to have a sharper edge. The paper is shown by the dotted line D. By altering the relative speeds of the drum E and the rolls B, by means of the expanding-pulley G, sheets of any desired size can be cut. The cutting-knives are sometimes placed inclined to the drawing-in rolls B, so that the sheet, instead of being cut into a rectangle, is cut into a rhomboid. Such paper is used chiefly for the manufacture of envelopes, this shape occasioning a smaller loss when the envelopes are cut out.

1059.



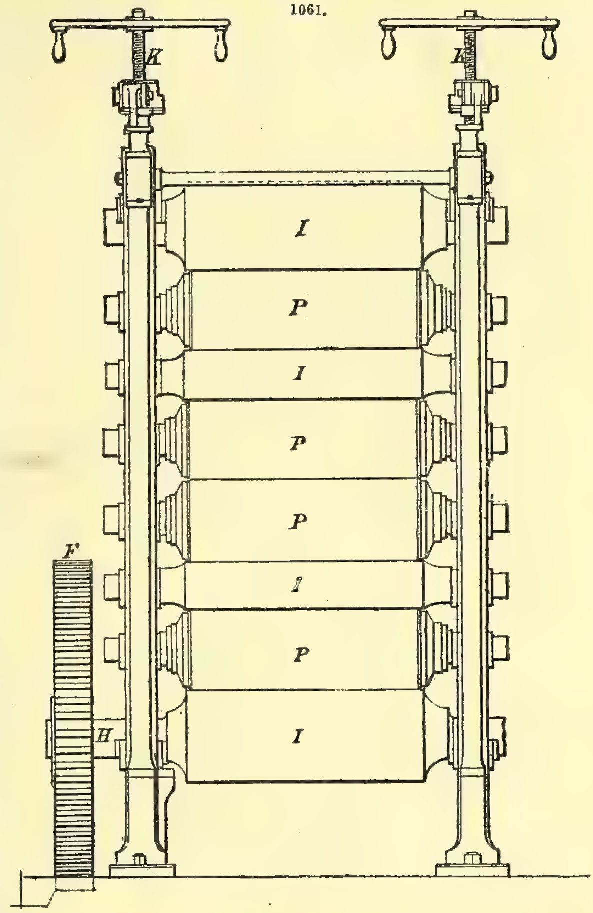
1060.



It is often necessary, as in the case of paper having a water-mark, that the sheet should be cut with great exactness, so that the device shall come exactly in the centre. The ordinary cutter cannot be relied on for this purpose, and, in its place, a machine called a "single-sheet cutter" is used (Fig. 1065). It consists essentially of a large wooden drum

A, fixed on a horizontal axis, over which the paper is led by a pair of drawing-in rolls B. The paper is held against the drum by a clamp worked by the arm C. The paper is cut by the knife E moving against the stationary knife D. After the cut, the drum describes part of a circle, the paper being still held, so that it cannot go back with the drum. As soon as it has gone far enough, the clamp is removed, and the drum returns, bringing the paper with it. The length of the arc through which the drum moves, and therefore the size of sheet, is regulated by the length of the crank-arm F. If, from any cause, the cut should not take place at the right time, the man in charge can, by pressing against the clamp, retard the motion of the paper, and thus bring back the cut to the right place. The small roller G is for the purpose of keeping the paper always tight.

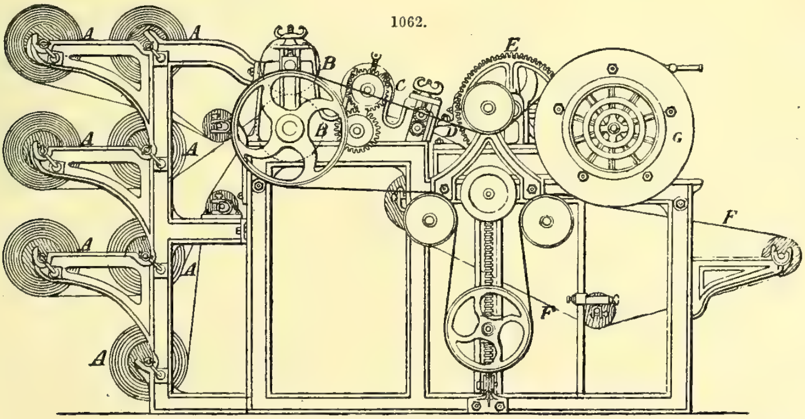
1061.



Soda-recovery Process. — In former years, the liquors in which rags, esparto, and other paper-material had been boiled, was run into a river or stream near; but now, owing partly to the fact that it is insisted on by the land-owners, but chiefly because it can be made remunerative, all such liquors are preserved, and the soda in them is utilized. The method adopted is to evaporate to dryness, and ignite the residue, which then contains the soda, originally used as caustic soda, chiefly in the form of carbonate, mixed with a quantity of silicate and other salts.

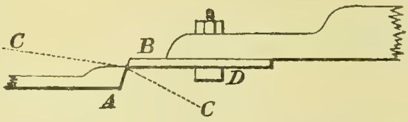
The ash so obtained is dissolved in water, sometimes filtered, and boiled with a quantity of lime sufficient to reconvert it into caustic soda, the lime at the same time being changed into carbonate. The latter is allowed to separate out by settling, and the clear liquor is run off. The carbonate of lime is washed once or twice with water, the liquor, if very weak, being used to

1062.

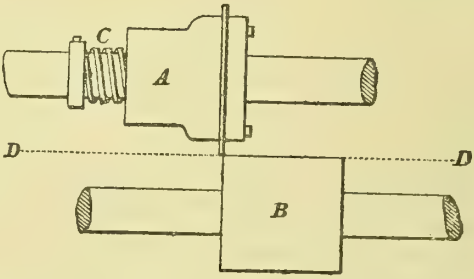


dissolve fresh ash, and then, in the best conducted mills, it is allowed to drain on filters, beneath which a vacuum is produced by an air-pump, similar to the arrangement used in alkali-works. Of course the whole of the soda cannot be recovered in this way: loss by leakage, in addition to that left in the fibre, must inevitably occur; this is generally replaced by fresh caustic soda, or good soda ash.

1063.

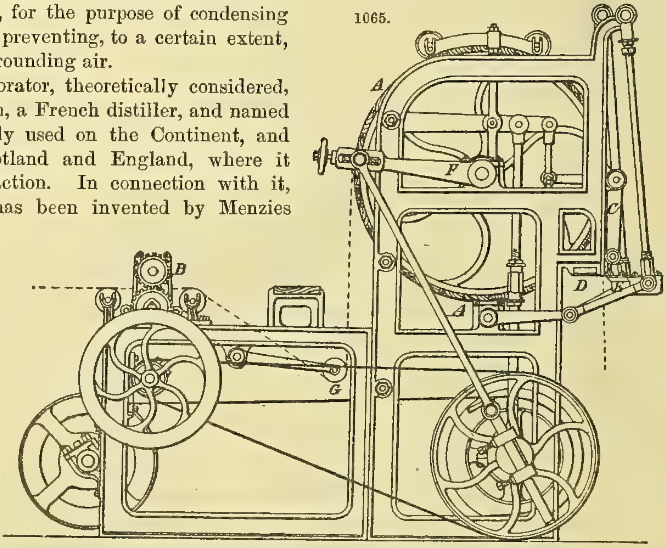


1064.



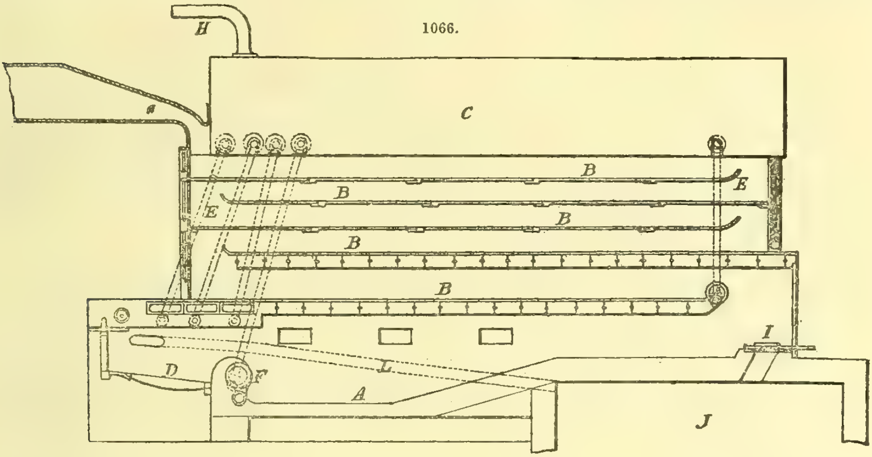
The apparatus for accomplishing the evaporation varies with almost every mill. In some, it is very primitive and crude, consisting perhaps of only a furnace for incinerating the residue, and over it a pan containing the liquor, the latter being heated and evaporated by the heat from the furnace. It is obvious that, with such an arrangement, a large quantity of heat must be wasted. To economise as much as possible of this waste heat, various plans have been suggested. That of Roeckner, of Newcastle, appears to be to a great extent efficacious. It consists practically of a series of shallow trays B (Fig. 1066) placed in a brick chamber, alternated so as to allow the heated air from the furnace below to play upon the surface of each in succession, on its way to the chimney, with which the whole system is in connection. Above the chamber containing these trays, is a large tank C containing a store of the liquor to be evaporated, placed there so as still further to economise the heat, and from which the liquor runs on to the trays. The furnace A below is of the ordinary reverberatory kind; below it, and connected with it by a kind of damper, is a large chamber J where the calcined residue from the furnace is put to cool, thus preventing any nuisance from the smell of the burning mass. The chamber is provided with a pipe L, through which the vapours pass into the furnace. Several pipes E from the furnace pass through the tank, to assist in warming the liquor. The residue, when cold, is drawn through doors from the chamber below the furnace. Roeckner has devised an apparatus (Fig. 1067), consisting of a small chamber containing a series of pipes A, through which, a stream of cold water constantly runs, in connection with the flue from his evaporator, for the purpose of condensing volatile bodies, and thus preventing, to a certain extent, contamination of the surrounding air.

1065.

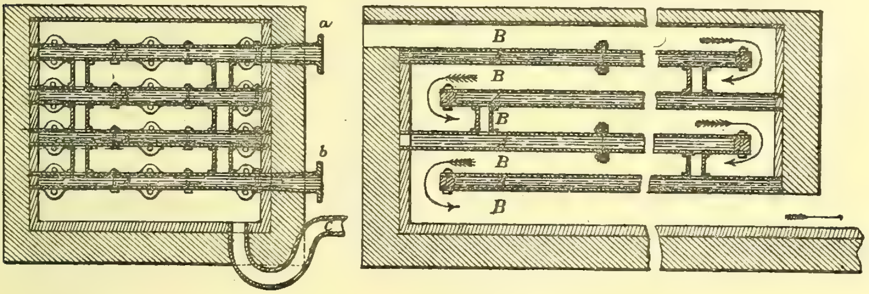


An economical evaporator, theoretically considered, is that invented by Porion, a French distiller, and named after him. It is largely used on the Continent, and at several mills in Scotland and England, where it has given great satisfaction. In connection with it, a "smell-consumer" has been invented by Menzies and Davis. It consists essentially of a large chamber, the floor of which is inclined slightly from the chimney. The liquor to be evaporated is run in at the end nearest the chimney, from a tank. Fanners, dipping about ½ in. into the liquor, revolve with great rapidity, and produce a very fine spray, thus presenting a very large evaporating surface. The evaporation is caused by the heat from the furnace on its way to the chimney. The "smell-consumer" consists of a fire-brick chamber, having courses of walls, built in such a way as to retard the draught somewhat, and so give time for the products of combustion from the furnace to be completely burnt. Time is all that is necessary, as the heat is quite enough, and there is always sufficient oxygen present. The doors are used for cleaning out this chamber. The tank is placed over this chamber, in order to warm the liquor, and thus still further economise the heat. The chamber is for the purpose of retaining any solid particles carried forward. The evaporated liquid is run from one or more of the doors along a spout to the pan, from which it is run into the furnace. The furnace is of the ordinary kind, but with two beds. Here the liquor is still further evaporated, and the residue is incinerated. If the latter operation is properly conducted, no nuisance from smells need arise, and the combustion in the smell-consumer is perfect. The draught is regulated by a damper. (Continued on p. 1508.)

1066.



1067.



General Considerations. *Varieties of Paper.*—Paper may be roughly classed under three heads;—"Writing," "Printing," and "Wrapping." The different varieties of each are almost endless: the following list gives the principal kinds.

Writing.—Machine-made, hand-made, tub-sized, engine-sized, account-book (machine and hand-made), envelope, &c., &c.

Printing.—Newspaper, magazine, book, plate, map, lithographic, music, coloured printings, bank-note, cheque, &c., &c.

Wrapping.—Bag-paper; grocery-papers; browns—thin, glazed and unglazed; air-dried; machine-dried, cartridge, mill-wrappers, sugar-blues, &c., &c.

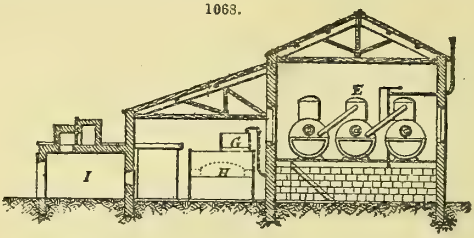
Selection of Site for Paper-mill.—In choosing a spot on which to build a paper-mill, the manufacturer has to take into consideration several very important circumstances. Chief of these is the necessity for having a large supply of water at command. Not only is a large quantity needful, but it should (see Beating, p. 1489) be free from impurities, such as suspended matter and iron. The former, it is true, can be removed by settling and filtration; the latter cannot, and is liable to injuriously affect the colour of the paper. Again, as a question of economy in working, it is advantageous to have convenient water-power; therefore for this, as well as for the former reason, paper-mills are usually situated on the bank of a stream. In choosing such a site, paper-makers are probably influenced by the fact that it affords a ready means for the removal of impurities. In properly conducted mills, where suitable apparatus is employed for evaporating the liquors in which the raw material has been boiled, the stream should not be polluted to any very great extent. Generally speaking, the greater the pollution, the more are valuable materials being loss to the manufacturer. It is obvious that the site for a mill should also be chosen with reference to its proximity to means of transit for the raw and manufactured materials.

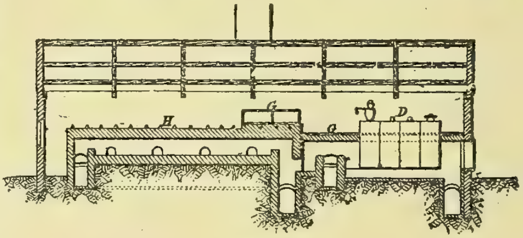
Soda-recovery Process (continued from p. 1507).—The temperature of the vapours in the chimney is determined by the speed of the fanners. When these run at high speeds, the fine spray reduces the temperature of the combustion-products coming from the furnace, so that in the chimney it is below 82° (180° F.). On reducing the speed, the temperature will soon rise to $204\frac{1}{2}$° (400° F.). An objection to the Porion evaporator is the volatilization of the soda, owing to its intimate exposure in solution to the heat of the furnace by the action of the fanners.

There has been lately erected in Lancashire an evaporator patented by Alfred Chapman, M.I.C.E., partner in the firm of Fawcett, Preston, & Co., Liverpool. In this (Figs. 1068–1071), the evaporation is effected at a low temperature in three vacuum-pans, with the unusual result that the concentrated liquor jellies after extraction from the third vacuum-pan, instead of taking the ordinary form of the concentrated products of other evaporators. It is said that this apparatus gives an excellent product, with great economy of labour and water, and with no drainage of foul liquor from the buildings. Observations extending over three months have proved that it evaporates 22 lb. of water from the liquor per lb. of coal used under the boiler, whereas other evaporators are considered to work well if 14 lb. are evaporated.

The waste liquor is discharged into the tank A, whence it is pumped by the donkey-engine B, through the feed-heater C, into the boiler D, which receives heat from the incinerating furnace H, and, in case of need, from an auxiliary furnace shown on the plan, under the feed-liquor heater. The steam produced in D is taken to the first vacuum-pan at E, and having heated its contents, the products of evaporation pass over into the tubes of the second pan; this, in its turn, gives up its products of evaporation to the third, whence they go to the condenser of the vacuum-engine F. Thus the heat from the furnace H is used for incinerating the concentrated liquor on its bed, for heating the feed-liquor in the feed-heater pipes, and for making steam out of the liquor itself in the boiler; this steam finally drives the donkey-pump and vacuum-engine, and causes the evaporation in the three vacuum-pans E. It is difficult to imagine a more economical apparatus.

1068.





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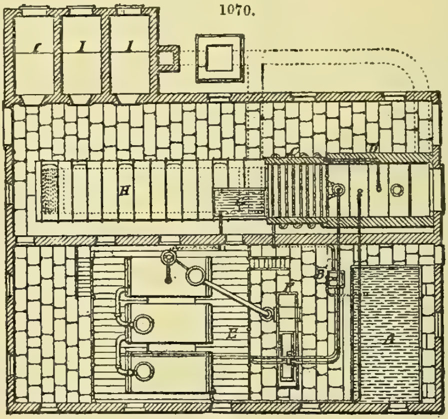
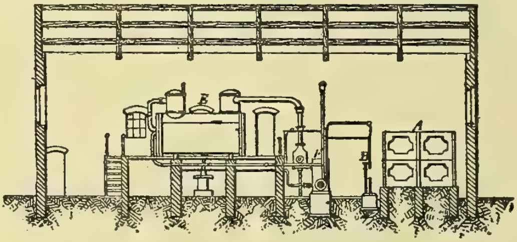




1071.

Extent of the Industry.—The Directory of Paper-makers for 1881 shows that in England and Wales there are 259 makers, employing 424 machines; in Scotland, 61 makers and 102 machines; in Ireland, 14 makers and 18 machines. These numbers include 41 makers of hand-made paper, using 173 vats, in England; and 2 makers, 4 vats, in Scotland. A rough estimate of the amount of capital invested in the paper industry may be formed on the basis that average mills would represent 20,000–25,000*l.* for every machine.

Imports of Paper and Paper materials.—Our imports of paper in 1879 were as follows:—

Printing- and Writing-papers—75,388 cwt., 109,172*l.*, from Sweden; 73,308 cwt., 150,438*l.*, from Belgium; 44,570 cwt., 79,692*l.*, from Germany; 12,448 cwt., 16,125*l.*, from Norway; 10,235 cwt., 20,137*l.*, from Holland; 9678 cwt., 35,942*l.*, from France; 9187 cwt., 26,657*l.*, from Austrian territories; 3274 cwt., 7108*l.*, from other countries; total, 238,088 cwt., 445,271*l.*

Paper-hangings—7059 cwt., 8351*l.*, from Sweden; 5583 cwt., 44,404*l.*, from France; 880 cwt., 2756*l.*, from other countries; total, 13,522 cwt., 5554*l.*

Brown, Waste, and other (unenumerated) sorts—94,874*l.* worth from France, 87,108*l.* from Holland, 83,299*l.* from Germany, 39,433*l.* from Belgium, 35,555*l.* from Sweden, 12,964*l.* from Norway, 11,593*l.* from the United States, 5194*l.* from other countries; total, 370,020*l.*

Millboard and Pasteboard—194,583 cwt., 100,759*l.*, from Holland; 111,903 cwt., 50,700*l.*, from Germany; 53,319 cwt., 29,954*l.*, from Belgium; 10,203 cwt., 8002*l.*, from Norway; 6711 cwt., 5007*l.*, from Sweden; 3579 cwt., 7918*l.*, from other countries; total, 380,498 cwt., 202,340*l.*

Linen and Cotton Rags—5457 tons, 96,641*l.*, from Germany; 2877 tons, 46,414*l.*, from Russia; 2540 tons, 28,758*l.*, from Turkey; 1941 tons, 30,178*l.*, from Belgium; 1784 tons, 32,011*l.*, from France; 1192 tons, 12,545*l.*, from Egypt; 1051 tons, 16,196*l.*, from Holland; 1086 tons, 12,093*l.*, from other countries; total, 17,928 tons, 274,836*l.*

Esparto and other Vegetable Fibres—68,910 tons, 376,284*l.*, from Tripoli and Tunis; 46,636 tons, 307,488*l.*, from Algeria; 44,091 tons, 357,531*l.*, from Spain; 2334 tons, 14,313*l.*, from other countries; total, 161,971 tons, 1,055,616*l.*

Pulp from Rags and Wood—18,190 tons, 148,018*l.*, from Norway; 4271 tons, 41,969*l.*, from Sweden; 1722 tons, 7517*l.*, from Holland; 752 tons, 6590*l.*, from British India; 735 tons, 5780*l.*, from Belgium; 605 tons, 5179*l.*, from Germany; 1532 tons, 15,015*l.*, from other countries; total, 27,807 tons, 230,068*l.*

Bibliography.—J. Murray, 'Practical Remarks on Modern Paper' (Edinburgh: 1829); L. S. le Normand, 'Manuel du Fabricant de Papiers' (Paris: 1834); G. Planche, 'L'Industrie de la Papeterie' (Paris: 1853); L. Müller, 'Die Fabrikation des Papiers' (Berlin: 1855); Proteaux, 'Manufacture of Paper and Boards' (Philadelphia: 1866); C. Hofmann, 'Manufacture of Paper' (Philadelphia: 1873); T. Routledge, 'Bamboo considered as a Paper-making Material' (London and New York: 1875); J. Dunbar, 'The Practical Paper-maker' (London: 1881); Tomlinson, 'Manufacture of Paper'; 'Paper-makers' Monthly Journal' (London: 1872); 'Paper-trade Journal' (New York: 1872); 'Papier-Zeitung' (Berlin: 1876). E. J. B.

PARAFFIN (Fr., *Paraffine*; Ger., *Paraffin*).

The paraffin of commerce, a beautiful, translucent, snowy-white, wax-like substance, is not, chemically speaking, a homogeneous substance, nor constant in its physical properties. The sp. gr. varies from 0·8236 to 0·9248. The fusing-point of commercial paraffin ranges from about 35° (95° F.), to 55° (131° F.); much higher fusing-points are occasionally met with, but specimens melting at 80° (176° F.) are of curious and scientific, rather than of commercial, interest. Within certain limits at least, and other things being equal, the higher the fusing-point, the more valuable is the sample. Paraffin is insoluble in water and in cold alcohol, slightly soluble in hot alcohol, and completely so in essential and fixed oils, benzol, ether, and carbon bisulphide; the solubilities of the different samples increase as their fusing-points decrease. As will be apparent, this property has important bearings on the refining process, as also the crystalline structure, which it assumes when the tarry matter is removed by distillation. In samples fusing at about 34°–38° (93°–100° F.), the crystals are large and well defined; while in samples fusing at 49°–55° (120°–131° F.), this structure is not so evident, though microscopic examination shows that, if less than $\frac{1}{100}$ part of the size of those in the former sample, the crystals are still there. Paraffins mix with stearine, palmitine, and resins, in all proportions; but it is to be noted, that the melting-points of such compounds are not nearly the mean of those of their ingredients; while the melting-points of mixtures of different paraffins are very nearly so. Another peculiarity of this substance is the condition of plasticity which it assumes, at a temperature very much below its fusing-point.

Chemically considered, paraffin is a mixture of the two elements, carbon and hydrogen; and the analysis of many samples, from different sources, demonstrates that these elements exist nearly in the same proportions as in olefiant gas. Consequently, good chemists, after careful investigation, have been led to conclude contrary to the general opinion, that the solid paraffins are mixtures of the higher olefines, which have a percentage composition of 85·7 carbon and 14·3 hydrogen. The chemical behaviour of these paraffins in the presence of reagents favours the theory which places them in the series represented by the general expression $CnH_2n +_2$; the letter n representing the number of carbon atoms in the compound molecule. In this so-called homologous series, which has as its first term methane or marsh gas (CH_4), the other terms are formed by successive additions of the compound molecule (CH_2), the second being ethane (C_2H_6), and so on, each member containing twice as many atoms of hydrogen as of carbon, plus two. The atomic weight of carbon being 12, and that of hydrogen 1, the carbon percentage will increase from 75 per cent. in the monocarbon paraffin, to 85·1 in the 20-carbon, and 85·31 in the 30-carbon; and it is evident that, though always approaching the theoretical percentage composition of the olefine (C_nH_{2n}) series, it could never reach it. It is, however, to be observed, that the percentage in the higher members comes so near, that analysis, owing to errors arising from defective method, cannot settle the question.

The lower hydrocarbons of the paraffin series are, at ordinary temperatures and pressures, gaseous; ascending the scale, we come to liquids under similar conditions, and after that, at about the 20th member of the series, to the solids. Where these have been isolated by fractional distillation, it has been found that, at every step, there is a rise in vapour-density, and boiling-point, and, in the solids, in fusing-point. In some samples of petroleum, many of the members have been found to exist. Ronald isolated eighteen from an American sample, and, apart from the chemical indifference which marks the series, the fact of the association of the higher with the lower undoubted paraffins, strongly favours the generally held opinion as to their family connection. In the laboratory of nature, it is more than probable that the entire series has been produced.

If a piece of solid paraffin is heated for some time in a closed vessel, it is broken up into paraffins of lower molecular value, and partly resolved into olefines; and the higher the structure of the paraffin, the more easily it is destroyed or degraded. This is important, as bearing on the processes of distillation and chemical treatment.

Manufacture.—Paraffin in the native, ready-formed state is widely distributed over the world. Dissolved in kindred oils, it is found in abundance in the United States of America and in Canada, and is known by the name of "rock-oil" or "petroleum" (see Oils, p. 1433). The yield of solid paraffin from American petroleum is not more than 2½ per cent.; in Upper Burmah, petroleum is produced containing from 5 to 10 per cent. of crude paraffin; in Galicia, Wallachia, and on the shores of the Caspian, along with petroleums, are found solid deposits which are richer in paraffin, known by the names of "naphthagil" or "neft-gil," "ozokerit," "ceresine" or "mineral wax" (see Wax—Ozokerit). The percentage in these deposits is from 15 to 40 per cent. Paraffin is also met with in bituminous deposits in various localities.

Large quantities of this substance are produced on the Continent, from brown coal or lignite; but in this case, as in that of the cannel coals and shales, it does not already exist, but is a product of destructive distillation.

The industry in Scotland has, during late years, attained considerable magnitude, as may be gleaned from statistics published lately by Calderwood. He estimates the shale distilled in Scotland, by eighteen firms who have monopolized the trade, at 850,000 tons; the crude oil produced, at 29,000,000 gal.; the naphtha and burning-oil, at 11,400,000 gal.; lubricating-oil, at 5,000,000 gal.; paraffin-scales, 9200 tons; and sulphate of ammonia, 4790 tons.

The principle of destructive distillation referred to is also involved in the manufacture of illuminating-gas. In both cases, heat is the active agent. The vessel or apparatus into which the shale or coal is put is called a "retort." Essentially it is a large bottle, made of materials fitted to withstand the action of fire, opening into a condensing arrangement, more or less simple, according to special requirements. In this, its primitive, simple construction, the one opening must needs serve three purposes, namely receiving the charge, allowing the coke to be taken away when the distillation is finished, and drawing off the gases. In practice, there are always two openings, sometimes one for each of the three functions. When heat is applied to the outside of a retort containing shale, from which air is excluded, decomposition takes place, and very numerous and complicated compounds are formed, which come away as vapour. On the degree of heat, however, depends the character of these, notably in this respect:—A very high heat, such as is used in gas-making, produces a maximum of lighter gases, which remain permanently gaseous. The paraffin-distiller knows that the dull-red heat, which will just suffice to loosen the bonds which bind the hydrocarbons to their clay-like matrix, will best serve his purpose; and though he is compelled to exceed the desired minimum, he does so with reluctance and from necessity.

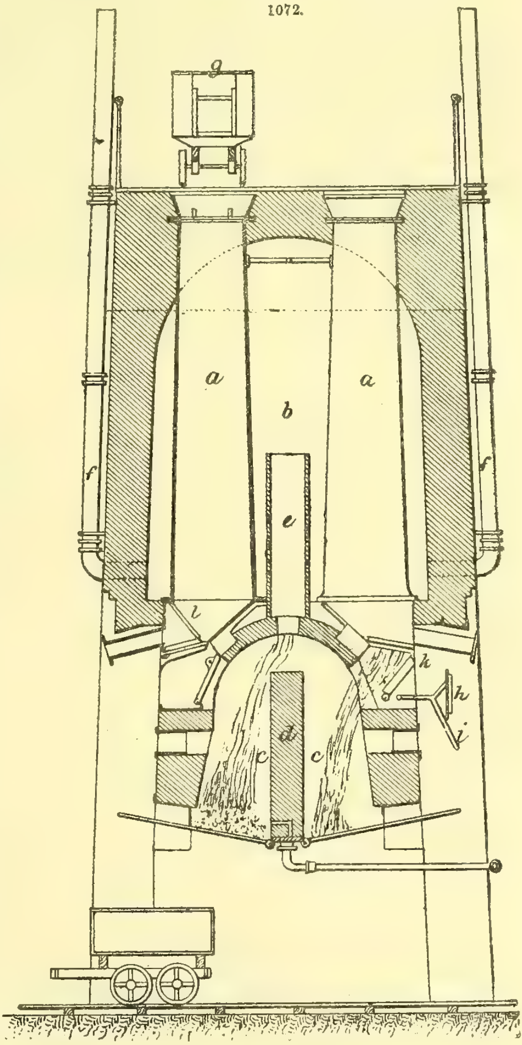
In practice, it is found that the chemical tie which binds the hydrocarbons to the shale, will not be dissolved by a temperature which would volatilize them if free. Again, all the contents of a retort do not come into immediate contact with its sides; and if the material in the middle of the retort is to get just the amount of heat necessary to set its gases free, it must be at the expense of that in proximity to its sides getting too much. Another difficulty arises from the fact that the hydrocarbons evolved have an extended range of boiling-point. It does not seem possible to completely overcome these difficulties; but we must appreciate the ingenuity and skill displayed by engineers who have constructed retorts which fulfil the chemical requirements in a high degree, and at the same time the commercial, which demand economy in labour, fuel, and wear and tear.

The horizontal retort is remarkably simple in construction. At one end of an oval-section body, of variable length and diameter, is the door by which the broken shale is put in, and closed by an air-tight lid. At the opposite closed end, it is connected with a hydraulic main, by a pipe 4–8 in. in diameter. The main and exit pipes are kept low, to favour the ready escape of the vapours, which are dense. Between the main and the retort, is a valve which closes the pipe, when the retort is being charged or emptied. From five to seven of these retorts may be built in one oven, and heated by one fire; and an indefinite number may be connected with the same main. The heat being very low, the condensing arrangements are simple. Steam at low pressure is now very generally introduced with beneficial effect—a gentle flow, carrying along with it the vapours as they are formed.

The vertical retort is more complicated in all its forms. As that invented by Norman M. Henderson, of the Broxburn Oil Co., to whose kindness the illustration and description are due, is much approved, it will be described in detail. It is now in extensive use in the principal oil-works in Scotland, having been erected in the Addiewell works of the Youngs Co., and at the Broxburn, Uphall, Oakbank, and several other works.

The retorts *a* (Fig. 1072) are 15 ft. long, having a cross-section of a flat-oval form. Four of these retorts are set into one oven, which is a high arched chamber *b*, closed at the top. Straight under the oven, is the furnace *c*, which is a capacious arched chamber, divided into two by the wall *d*, rising to near the top of it. It is connected with the oven by the flue *e*, which rises about 6 ft. from the centre of the arch. This flue acts as a screen to prevent the four retorts, which surround it, from being overheated. The products of combustion enter the oven by this passage, and being hot, float to the top of the arch, replacing the cooler products previously there, which, as they cool, gradually fall down, and pass out at the exit pipes *f* placed at the bottom of the oven.

1072.



The retorts are charged from hutches *g*, run on rails along the top of the building. The doors on the top of the retorts are opened, and the hutch contents are tipped direct into them. The doors are then shut close until the charge is spent, which takes 16–20 hours. The retorts are closed below with a removable door *h*, and when the charge is exhausted, this door is taken off by a simple implement *i* for the purpose, and at the same time, a little valve or shoot *k* folds back from an opening in the top of the furnace-arch, and the spent shale, falling down by its own weight, is shot directly into the furnace below. The retort is bevelled at the bottom, so as to let the removable door be made of smaller and handier size, and be within easy reach of the workman. The retorts are emptied in rotation, at intervals of 4 hours, from each side of the furnace alternately, so as to keep the temperature equal throughout. There is little carbon left in the spent shale, and too much draught would extinguish it, so the furnace and oven are constructed so as to cause a very gentle influx of air. The slow current also enables the retorts to get full advantage of the heat of the combustion-products. The spent shale falls into the furnace black though hot, but in 5 minutes it is glowing brightly. It continues to burn for 8 hours. In this manner, is produced with certainty the mild heat fitted to give the highest percentage of products, and the best quality of crude oil. The temperature is thus beyond the influence of the workman, and skilled labour is rendered unnecessary. The non-condensable gases are let into the furnace, and burned along with the spent shale. From what has been said, it will be seen that the lower end of the retort is the coolest part ; consequently the oil-vapours are led off from the bottom. Super-heated steam is blown into the top of the retort, so as to sweep the oil-vapours out of the region of heat as soon as formed, to prevent their being broken up into lighter and gaseous products, the heavier being the more valuable. A series of pipes is arranged along the side of the oven, and through these the steam is passed, so that it enters the retort super-heated above the temperature of the oven, and so diffuses the proper distillation temperature throughout the whole mass of the shale; consequently no part requires to be overheated.

The old vertical retorts are heated with coal-fires, and are generally worked at much higher temperatures. The results are altogether dependent on the workmen, as, with such powerful fuel, great care and skill are required to equalize the temperature. At the bottom of Henderson's retort, is a grating *l* (Fig. 1072), which prevents the shale getting down into the corner which is out of the heat; and when the bottom plate is taken off, this grating falls over the oil outlet, and protects it from the spent shale. When the spent shale is thoroughly burned, the bottom plate of the furnace folds down, so as to drop the ashes into a hutch below. To extinguish the embers, the hutch is passed through a tank of water, on the way to the refuse heap. The advantages claimed for the Henderson retort over the old vertical are: a larger yield of the more profitable materials, namely, paraffin-wax, lubricating-oil, and ammonia; increased yield ; saving of fuel ; long life, and less cost of maintenance; and reduced loss in refining. The saving of fuel, maintenance, &c., is equal to 1*s.* 6*d.* a ton of shale distilled, or 4*s.* 6*d.* on each 100 gal. of crude oil. Assuming, however, the yield of crude oil and ammonia to be the same from either retort, the profit can be illustrated in the following manner :—

Result from 100 gal. of crude oil :—

Henderson's.			Old Vertical.		
		d.			*d.*
5·00 per cent.	naphtha at 4*d.*	20	5·00 per cent.	naphtha at 4*d.*	20
35·00 „	burning-oil at 4*d.* ..	140	40·00 „	burning-oil at 4*d.* ..	160
18·00 „	lubricating-oil at 8*d.* ..	144	13·00 „	lubricating-oil at 8*d.*	104
10·50 „	scale at 30*d.*	315	8·00 „	scale at 30*d.*	240
31·50 „	loss		34·00 „	loss	
100·00		619*d.*	100·00		524*d.*

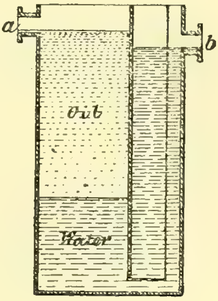
There is thus a difference of 95*d.* or 7*s.* 11*d.* in favour of Henderson's, arising from increased value of products, which, added to the 4*s.* 6*d.* saving in manufacture, amounts to 12*s.* 5*d.* per 100 gal. of crude oil distilled, or 4*s.* 2*d.* per ton of shale.

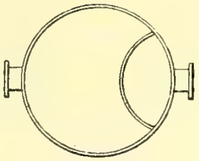
The products of distillation are received into the hydraulic main, which is a long cylinder laid on its side, extending along the bench of retorts, the exit pipe of each retort dipping into it. At the bottom, is collected the water, partly produced from combustion, and partly by the condensed steam. In this, are dissolved various salts of ammonia; it is technically known as ammonia-liquor. Over this in the main, is the crude oil. At the end of the main, before it enters the condenser for the purpose of separating the already condensed watery and oily products, is a trap and separator. The trap is to prevent the loss of vapour, and at the same time to allow the liquids to pass. The separator, Figs. 1073 and 1074, is a vessel of considerable depth, say 3 ft., divided into two portions by a vertical partition, which is carried not quite to the bottom. The oil and water are together led into the larger division of the vessel. The oil, being the lighter body, floats on the top, and by an outlet *a* from this larger division, near its top, is led away to the crude-oil tank. The water, by virtue of its gravity, finds its way under the partition, into the other portion of the separator, seals up the passage against the oil, and, by an outlet *b* placed at a level a little lower than the oil-outlet escapes into its proper receptacle, to be afterwards treated for the manufacture of sulphate of ammonia. The uncondensed gases are led from the main to a series of condensers, where they are cooled down to the normal temperature ; and the permanent gases are led away either to be burned in retorts, or to a coke tower, where they are brought into intimate contact with heavier oils, which absorb them. The condenser is in some cases almost exactly like those used in gas-works, its base being a large chest or chests with faucets at top, on which are erected long inverted U-shaped pipes, or condensers.

Generally all the oily products of combustion are collected into the tank, and known as "crude oil." This, after being thoroughly freed from water by sediment, is pumped into a large cast-iron still, and heat is applied till all the volatile portion is driven over. The residue left in the still is merely cinder or coke, which is broken up and sold for the manufacture of ironfounders' blacking.

The condensed distillate is known as "once-run oil." This is pumped into the refinery. The arrangements in a refinery are generally of this nature—At a high level, are one set of large iron, or wooden lead-lined, tanks, which are intended for the acid treatment of the oils at the various stages. At a lower level, is placed another set of similar size, for the treatment with caustic soda. In each tank, which may hold several tons of oil, is a stirrer. One of the most efficient, is that designed by A. C. Kirk, on the turbine principle, and which, for the acid treatment, is driven at the rate of 200 rev. a minute. The stirring is also very effectively done by pumping air into the mass of oil; and this simple method of agitation has much to recommend it, as there is nothing exposed to the corrosive action of the acid, save the iron pipe through which the air is injected. The once-run crude oil is pumped into one of the high-level agitators, with 2½ per cent. of sulphuric acid, sp. gr. 1·840, or refuse acid, in whole or in part, which has formerly been used in the more advanced stages of the process. The oil assumes a beautiful purple tint under the action of the acid, as the brown decomposed matter settles down with the acid. What the precise nature of the reaction is, does not seem to be wholly understood. It appears, however, that the hydrocarbons which have a deficiency of hydrogen yield that hydrogen more readily than those which are saturated, and are so decomposed by the dehydrating agent. Theory would suggest that instead of destroying, it would be more rational to add the required hydrogen, and so build up paraffins, but hitherto this has not been found practicable. After having settled, the acid tar is run off by a valve below, and the supernatant oil is run into the lower-level agitator, where 1½ per cent. of caustic soda, 1·35 sp. gr., is added, with slight agitation. This treatment, besides neutralizing the trace of acid left by the last operation, removes the congeners of phenol. The sediment is known as "refuse soda."

1073.



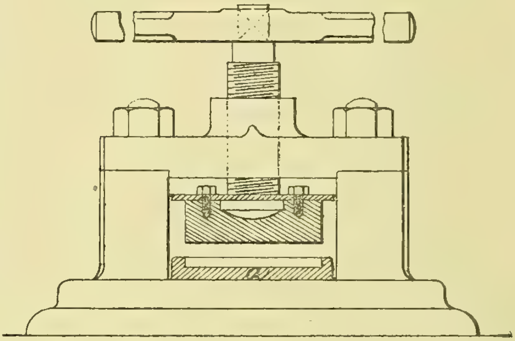


1074.

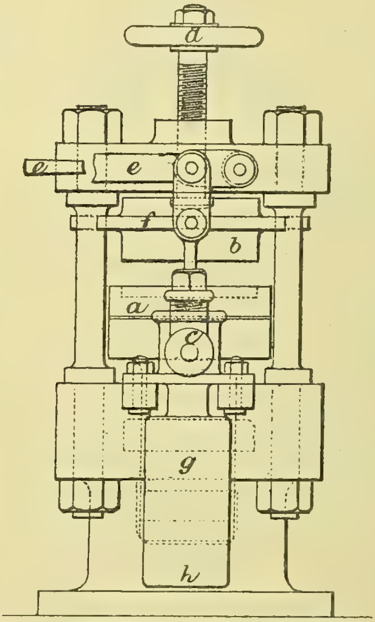
After the soda treatment, the "once-run treated oil" is again pumped into a still, say 6–7 ft. in diameter, and 16–20 ft. long, of malleable iron, cylindrical in form, laid horizontally. Between the fire and the boiler-plate forming the bottom of the still, is a fire-brick arch, with portholes at the flanks, for the purpose of spreading the furnace-flame equally over the bottom of the still. The oil-still is united, by a goose-neck connection, to an iron condensing-worm of considerable dimensions, immersed in a tank kept full by a continual influx of water, which, when heated, escapes by an overflow. At the extreme end of the condenser, is placed a separator, as before described. The distillation is aided by steam. The still has a manhole on the top, and a valve at one end of the bottom, by which to run off the tarry residue. Up to this point of the process, no attempt has been made at separation of the products; but now advantage is taken of the fact that the oils of lighter gravity, distil over at a lower heat, and that as the process of distillation is continued, and the heat is increased, the heavier pass over. During the distillation, the sp. grs. are watched, and the flow of the distillate is diverted to separate tanks, as the required densities are reached. It is usual to make one division when the sp. gr. at the worm-end reaches 0·790, and another at 0·850, when paraffin begins to show. The naphtha and light-oil fractions, after another acid and alkali treatment, are again distilled and fractionized. The very lightest portion, such as is obtained from the coke tower, is used for the production of illuminating-gas, by the impregnation of atmospheric air with its vapour, by simple agitation in a portable gasogen. Naphtha of a sp. gr. of 0·735 is used as a solvent in many of the arts, and also in the subsequent process of refining the wax. That at 0·765 is a heavy spirit, economical for the latter purpose, and safer. These are all volatile at a heat below 100° (212° F.), and are consequently called "spirit." The light-oil fraction, on redistillation, is again divided into "No. 1 burning-oil," 0·800–0·810, No. 2, 0·810–0·820, and No. 3, 0·820–0·830. The oils between this latter sp. gr. and 0·875 are inferior, and used for open-air lamps, or torches, or machinery cleaning, as they possess little lubricating properties. "Washed oils" are those which have been finished by chemical treatment, but an oil finished by distillation is considered the best for burning. The latter fraction of the once-run is cooled by the refrigerating machine of Siddely and Mackay, described under Carbolic Acid (p. 674). The frozen oil containing paraffin is bagged, or put into a filter-press, and after it has been reduced in bulk by filtration, it is spread on canvas wrappers, and pressed in an ordinary hydraulic press. The residue left in the bags is called "scales"; the filtered oil, "blue oil," after treatment with 3 per cent. of sulphuric acid and 1 per cent. of soda, is again, after distillation, cooled down, and crystallization once more shows itself in the formation of paraffin of improved colour, but lower fusing-point. This is separated as above, and the oil, after another treatment, is used for lubricating purposes, and has a sp. gr. of 0·875–0·885. In the several distillations, the early fractions are reserved, and sent to the oil-tanks which contain oil of like gravity and purity; and the latter fractions are sent back in the process for further treatment, as they are less pure. These are the principles which guide the oil-refiner, though practice may vary in details. The tarry residue left in the still is either coked down, in a cast-iron still, or sold as a coarse grease.

This conducts the reader to a distinct stage of the process, namely the refining of the scales.

1075.



1076.

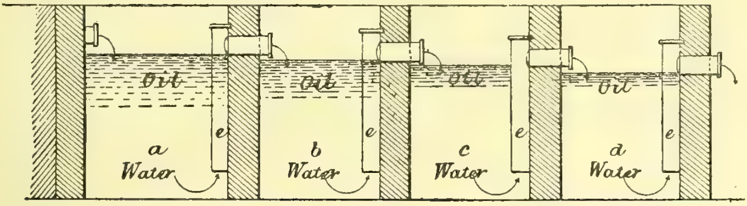


Refining.—The solid residue, after hydraulic pressure, is sold to the wax-refiners as "paraffin-scales." If the fusing-point is over 48° (118° F.), it is called "hard," if below this, "soft" scales. When the previous treatments have been well carried out, and the latter pitchy products of distillation cut off in time, the scales will crystallize well and refine easily. Good scales should yield 80–85 per cent. of refined paraffin. The 15–20 per cent. is made up of oil, water, dirt, and degraded greasy hydrocarbons, which must be washed out, or destroyed. As this loss is a very important item to be taken into account by the refiner, some ready means of testing any sample is desirable. An analysis is impracticable from the nature of the material. As a relative test between sample submitted and bulk delivered of same make, the hand screw-press, Fig. 1075, has been introduced. It does not determine how much oil a sample contains, for the best refined scales will not yield their oil to any pressure, nor even their water, within several per cents., but it simplifies the problem very much when, for purposes of comparison, there are two samples of the same dryness. The press is used thus. The cast-iron saucer *a* is taken out of the press; 14 discs of blotting-paper are cut exactly to fit its inside, and two of linen, which latter should be very fine and of close texture; 5 folds of blotting-paper are placed neatly in a saucer, then one fold of linen. On this, 250 gr. of the finely-powdered sample are carefully spread, and covered, first with the disc of linen, and then with 5 folds of the bibulous paper. The saucer is then put into the press, and the power of two men, one on each end of the lever, is applied. After a minute, the pressure is relieved, and the 10 folds of paper, which will have imbibed most of the oil, are replaced by the other four fresh pieces; the same pressure is applied, and the sample is allowed to remain under pressure for 10 minutes, when it is taken out. The very neat sandwich is opened up, the cake is weighed, and the difference between the two weighings is noted, and reduced to percentage. It is of importance that all this should be done in a room carefully maintained at 15½° (60° F.). A better press, as affording a means of estimating the actual pressure applied, is shown in Fig. 1076. It is wrought by hydraulic pressure, and is furnished with a pressure-gauge. The base of the press forms the cylinder, and the dotted lines show the piston, widened at top, supporting a movable saucer *a*, which is pushed by the water in the cylinder by a force-pump *c* against the stud *b*. When the operation has been completed, and the water let off, the piston is pushed down by a screw *d*; then by reversing the screw the press is opened. The pump-lever is at *e*. A pressure-gauge, omitted from the drawing, shows the amount of pressure applied. The plate *f* notched at the corners, slides on columns, and acts as a guide to the stud *b*. The hydraulic cylinder with piston is at *g*, and the water-tank for the pump at *h*. The water and dirt may be estimated by obvious methods. It has been the practice of one of the largest English firms, to subject scales submitted to a further test, by melting, and mixing with strong acid (sulphuric), which destroys the low greasy bodies.

To a great extent, the process of refining paraffin-scales is one of recrystallization. The lower paraffins and impurities are much more soluble in their oils and naphthas, than the higher and better paraffins, which crystallize, and separate easily from the mother-liquor containing the former. The purification is accomplished in different ways, but attention will be confined to one system, which is perhaps as economical as any, while as to the quality which can be produced by it, there is no question.

The scales are melted in a large pan, by steam introduced directly into the mass, by a bent coil of malleable iron pipe, say of $1\frac{3}{4}$ in. diameter. When it has been boiled, it is allowed to deposit what mechanical impurities it contains. It is well to have this pan with a tapered bottom, and a large valve below to let off the water and as much dirt as possible. The water is collected in a large separator, constructed on the principle mentioned before, as there is always some paraffin that escapes with the water and dirt. This separator should be very capacious. The same arrangement should be in connection with every pan where there is boiling with open steam, or contact with water; and the water from all these should be led into a very large compound separator, constructed as shown in Fig. 1077. The arrows show the direction of drainage. Division *a* will intercept most of the oil, but a little may escape to the second and third divisions *b c*. The separator with division walls is made of brickwork cemented. The pipes, open at top, so as to give facility for cleaning, may be of fire-clay or iron. This first melting-pan has a tap at say 18 in. above its bottom, and when the water and dirt have subsided below this, the clean melted scale is siphoned off into another pan, where it is mixed with 25 per cent. of shale naphtha, or that which has been previously used at a later stage of the process, and is consequently comparatively pure. This mixture is now allowed to run into shallow moulds, of such size that two cakes will cover the platten of the hydraulic press, and about $\frac{3}{4}$ in. thick. The press used is that fully described in the article on Candles, p. 587. When cold, each cake is put into doubled mats of coco-nut-fibre, covered inside with canvas, in form like the covers of a book, with the edges thickened by a doubling over of the matting. One of the presses referred to will hold about 80 of these cakes in their wrappers, with wicker mats at frequent intervals to stiffen the two columns of 40 cakes each. When the pressure is applied, the oil flows away in streams, carrying along with it the impurities and low greasy paraffin into a tank below. After standing say 3–4 hours, till the other presses of the set have been filled, the cakes are taken out, and represent about $4\frac{1}{2}$ cwt. of cake of a much paler complexion than when put in. The expressed wash is submitted to distillation, and the naphtha obtained may be used over again; the paraffin, after pressing, is either mixed among the scales, or kept for producing a refined wax of low fusing-point. The paraffin, which, along with dirt and water, escaped from the first melting-pan, is found as a cake on the separator, and is just returned to the pan at the next filling. The dirt, after mixing with a little crude oil, is bagged, and steamed in a vessel over the separator.

1077.



Thus the first stage of refining is disposed of. The once-pressed cakes are again treated in the same manner, either with pure naphtha, or with the wash derived from a third pressing. The pressing is done in a separate department, where another set of presses are erected, over a tank to collect the wash. This wash, as has been indicated, may be used for a solvent for the scales at the first stage. The cakes, when taken down, are nearly white; they are again melted, as before, but this time in every case with pure naphtha. It is very important that, in the distillation of this, it should have been carefully fractionated, so as to have no burning-oil left, as any trace of this would leave an odour with the material, which would lower its value. The cakes, when cold, are put into the press again, and come out clear and transparent, but smelling strongly of naphtha; to remove this, they are put into a still or rectifier, heated with a gentle fire, and agitated by a pierced coil of iron pipe, admitting steam into the liquid. The rectifier is connected with a very capacious condenser, so that the naphtha is saved for future use. The wash from this third pressing is concentrated by distillation, and either sent back a stage in the process, or caked, and pressed to finish with another wash, as "refined paraffin," of low fusing-point. The fusing-point of the finished wax, between wide limits, is under the control of the refiner.

The last and finishing stage of the process is the treatment with animal charcoal. The rectified paraffin is freed from water, and put into a double-cased pan. Between the casings, steam at 30 lb. pressure is admitted, which dries the paraffin. Some 5–10 per cent. of freshly burned animal charcoal, as fine as flour, is stirred for ½ hour among the liquid, and then allowed to subside. When clear, which it will be in about an hour, it is run off, at a point just above the sediment, into a filter. This must be of peculiar construction. The case is a jacketed cylinder, closed at bottom, except a small hole with female screw. Another light cylindrical framework of smaller size is inserted in this, and fixed in its place by a male screw, fitting into the hole in the outer case. This screw is a hollow pipe, through which the filtered paraffin escapes. The inside perforated frame is covered with bibulous paper, and the hot paraffin is led from the pan, and allowed to fall between the outer and inner frames. It finds its way through the pores of the blotting-paper, into the inside frame, and escapes by the bottom hole into its receptacle. The unfiltered paraffin is kept hot and liquid by the steam confined in the outer case, otherwise filtration could not go on. The water-white liquid is now put into the moulds to cool, and next day the cakes are ready for boxing. It will be seen that the processes, though simple, are tedious; and in practice, a week elapses, counting from the time when the scale is melted, till it is weighed, and put into cases for sale. It is, however, the residues of the different operations which are most troublesome. One that has not been noticed is the charcoal left in the bottom of pan. More than its own weight of paraffin adheres to it, when all that decantation can do has been done. It has been found best to dissolve out the paraffin with repeated washes of naphtha, which can go to the third wash of the process. Any naphtha remaining can be removed by retorting, and the char be either sold to blacking-makers, or, after reburning, be used again for refining.

Modifications of this method, and other methods, have been adopted, but as these are alluded to in the article Candles, there is no occasion to repeat them here.

The paraffin refined block should be of an opalescent whiteness, perfectly free from taste and smell. When two pieces are struck together, they should emit an almost metallic sound. It should be free from scaliness, and smooth on the surface. Quick cooling and thorough washing and pressing favour this.

The uses of paraffin are numerous. The greatest quantity is employed in the manufacture of candles. It is also used for tapers and vestas, and inferior qualities in the manufacture of matches. It is used by calenderers for sizing and glazing their fabrics. It is also said to be used to impart a finish to woollens, and in some patent process for waterproofing. If the new process of tanning of leather by bichromate of potash should be a success, a very considerable quantity of paraffin of medium quality will be required. To the chemist, it is, from its cleanliness and other properties, fitted to replace other oils in high-temperature baths; and from its indifference to chemicals, is useful for coating any frail substance, such as paper, so that he can improvise a vessel that will hold water or the most corrosive acid or alkali. It is invaluable to the electrician as an insulator, and, when mixed with indiarubber, it imparts to it the property of setting solid when cooled, after it has been melted by heat. A special quality of high melting-point is manufactured for the purpose of coating the inside of barrels holding beer for export.

Imports.—Besides the paraffin manufactured in the United Kingdom, considerable quantities of foreign are consumed. Our imports in 1879 were:—34,273 cwt., value 82,728*l.*, from the United States; 21,213 cwt., 70,591*l.*, from Germany; and 296 cwt., 622*l.*, from other countries; total, 55,782 cwt., 153,941*l.* H. L.

(See Alkalies—Ammonia; Candles; Coal-tar Products; Gas [Coal]; Oils—Mineral; Wax—Ozokerit.)

PEARL AND CORAL.

Two marine products bearing some resemblance to each other in origin, occurrence, mode of procuring, artistic application, and value, are pearl and coral.

Pearl (Fr., *Perle*; Ger., *Perle*).—Many molluscs line the interior of their shells with a coating formed of alternate layers of animal membrane and carbonate of lime; this, in some species, assumes a nacreous or pearly lustre, and forms the substance known as "mother-of-pearl." A superabundance of this secretion is often produced in drops or tuberosities, adhering to the interior of the shell, or lodged in the fleshy part of the occupant; these form the "pearls" of commerce. The formation of mother-of-pearl is evidently a natural and unvarying process with certain species of mollusc, though little research has been made as to the conditions which favour or retard it. The production of pearls, on the other hand, at least in the case of the true pearl mussel, is accounted accidental (possibly on insufficient grounds), and is generally attributed to disease or injury suffered by the occupant of the shell. This seems to be borne out in some measure by the following experiences gained in the pearl-fishery:—(1) When the shells attain great size, with a smooth, clean exterior, free from excrescences, holes, or other blemishes, indicating full and healthy development of the animals, and particularly noticeable where their occurrence is sparse,—there pearls will be extremely scarce; (2) where they are closely crowded, deformed and stunted in growth, studded with excrescences, and honeycombed with small perforations penetrating into the nacre,—there pearls will abound. Sometimes 100 pearls may be found in one shell, but in that case, few, probably none, will have a commercial value.

Sorts and Sources.—True pearls are formed only in bivalve shells, but handsome nacreous formations are obtained also from some univalves. The species whose productions are known in commerce are as follows:—(1) The true "pearl-oyster" or -mussel (*Avicula margaritifera*), yielding the most valuable pearls, while the shell itself is valueless; (2) the mother-of-pearl mussel (*Meleagrina margaritifera*), chiefly valuable for its mother-of-pearl, the shells being 6–18 in. across, while the pearls found in them also possess considerable value; (3) the conch-pearl or fountain shell (*Strombus gigas*); (4) the giant clam (*Tridacna gigas*), giving dull, opaque-white pearls; (5) *Pinna squamosa*, black and red; (6) seed-pearls from *Placuna placenta* [*orbicularis*], lead-coloured; (7) the common oyster (*Ostrea edulis*); (8) the horse-mussel (*Modiola vulgaris*); (9) the chank (*Turbinella scolymus*), pink pearl; (10) the "green snail" (*Turbo olearius* [*marmoratus*]); (11) the "Turk's cap" (*Turbo sarmaticus*); (12) the "ear-shells" or "aurora-shells" (*Haliotis spp.*), including the "ormer," of the Channel Islands, *H. iris*, of New Zealand, *H. Mida*, of the Cape, *H. rufescens*, *H. splendens*, and *H. Cracherodii*, of Japan and other localities; (13) the Chinese "pearl-mussel" (*Anodonta herculea*); and (14) the river-pearls obtained from *Alamodon spp.*, *Unio spp.*, and other river-frequenters.

River-pearls, the produce of fresh-water mussels, occur in the mountain streams of Scotland, Ireland, Lapland, Bohemia, and Canada. The marine pearl-fisheries are confined to a portion of the Persian Gulf; the Tinnevelly Banks, on the Ceylon coast; the E. Archipelago; the coasts of Australia, and the lagoons of many of the S. Pacific Islands; and Central America, in both oceans.

Fresh-water pearls are almost always of greatly inferior lustre and value, yet specimens worth 3–4*l.* each are not unfrequently found, and individuals have been known to fetch 50–100*l.* The Scotch pearls have long been famous. During the years 1761–4, London is said to have received pearls to the value of 10,000*l.* from the rivers Tay and Isla. In the dry summer of 1862, there was an unprecedented discovery of pearls in Scotland, the average value fluctuating between 46*s.* and 50*s.*, while 5*l.* was considered a high figure. The estimated value of the total findings in 1865 was 12,000*l.* Prices have since advanced considerably. The Bohemian fisheries are confined to the Horazdiowitz district of the Wotawa.

During the summer months, the Arabs prosecute a small pearl-fishery along the coasts of the Red Sea. The captured molluscs are taken ashore and exposed to the sun, when they quickly open; they are then examined for pearls, and thrown away. The headquarters of this fishery is Jedda. The shipments of mother-of-pearl from this fishery from Alexandria are said to amount to about 12,000 cwt. annually, less than half coming to Birmingham. The pearl-mussel fishery in the Persian Gulf, principally on the banks of the island of Bahrein, is also in the hands of the Arabs. The best beds are said to be level, and formed of fine whitish sand, overlying the coral, in clear water. About 4000–5000 boats are engaged, and the annual value of the harvest may be placed at 600,000*l.* The beds occur at all depths down to 18 fathoms, and probably lower; the chief diving is in 4–7 fathoms. The season lasts from April till September. The shells are mostly taken first to the little port of Lingah, whence a considerable quantity of mother-of-pearl is shipped direct to London, and a lesser amount to the Continent. Many of the pearls go to Bombay, especially those of yellowish colour and perfect sphericity; Bagdad is a great market for the seed-pearls, and those of white hue. The Persian Gulf shells that reach here are mostly small, and dark-edged, but they fetch a better price than Panama and Tahiti shells. The imports are seldom less than 3000–5000 cwt. yearly. The values (in *rupees* of 2*s.*) of the exports from Persian Gulf ports in 1879 were as follows:—from Bahrein: 1000 *r.* to India and 300 *r.* to Persian coast and Mekran, of mother-of-pearl; 18,00,000 *r.* to India, 3000 *r.* to Red Sea and Aden, 4000 *r.* to Persian coast and Mekran, and 4000 *r.* to Koweit, Bussorah and Bagdad, of pearls; from Bushire: 14,000 *r.* to England, of mother-of-pearl; from Lingah: 50,000 *r.* to England, 20,000 *r.* to India, and 4900 *r.* to Persian coast and Mekran, of mother-of-pearl; 22,25,000 *r.* to India, and 15,000 *r.* to Koweit, Bussorah and Bagdad, of pearls. Thus the total ascertained exports had a value of 41,37,200 *r.*, or over 40,000*l.*

The Ceylon or Tinnevelly fishery is situated on the W. coast of Ceylon, in the Gulf of Manaar, southwards of the island of that name, and along the opposite coast of the Indian continent, near Tuticorin. The banks lie in groups: the first, opposite the village of Arippu, comprises the so-called Peria-Par, Peria-Par Karai, Cheval-Par, Kallutidel-Par, and Modaragam-Par; facing the village of Karaitivu, is the bank of that name; and off the village of Chilaw, are Karakupanai-Par and Jekenpedai-Par. These banks are 6–8 miles from the shore, and 5½–8½ fathoms below the surface. They consist of masses of rocky ground, rising from the sandy bottom, and are probably exposed to ocean currents. These grounds are under the control of an Inspector appointed by the local government, and are worked exclusively by the government, who employ native divers, and give them ¼ of the proceeds. Experience has shown that few pearls, and those of little value, are to be found in molluscs under 5 years old; during the 5th–6th years, the value doubles, and is said to double again during the 7th year; the pearls are immature and imperfect if removed too soon, but the animal is liable to death or destruction if left too long. Intervals are therefore allowed to elapse between the fishings, varying in length according to the reports of the inspector. Until 1863, there was but little system in the operations; the yields of the fisheries had been:—1796–1809, 517,481*l.*; 1814–1820, 89,909*l.*; 1828–1837, 227,132*l.*; 1855–1860, 117,454*l.* In 1863, 22 days' fishing produced 11,695,000 oysters, whose yield of pearl was valued at 51,018*l.* The next fishing was in 1874, when 1,700,000 oysters gave 10,120*l.* worth of pearls. The fishing of 1877 lasted 30 days, and afforded 6,850,000 oysters, giving pearls to the value of 18,952*l.* The 1879 harvest was unexpectedly good; 12 days' fishing produced 7,650,000 oysters. The fishery of 1880 lasted from Mar. 9th to April 2nd, and the 11 days' operations resulted in a take of 11,500,000 oysters. This year's (1881) report states that 60,000,000 oysters might be fished, and might realise 60,000*l.*, the sample pearls fished giving the shells an average value of 10–12 *rupees* (of 2*s.*) a 1000. The fishing is conducted with extreme regularity. The divers relieve each other at intervals; when the boats come ashore, their harvest is removed to a shed, ¼ being handed to the divers as their remuneration.

After the pearls are collected, they are classified, sized, and valued. The classification is as follows:—(1) *Anie*, pearls of perfect sphericity and lustre; (2) *anathorie*, failing in one of these points; (3) *masengoe*, failing slightly in both points; (4) *kalippo*, failing still more; (5) *korowel*, double; (6) *peesal*, misshapen; (7) *oodwoe*, beauty; (8) *mandongoe*, bent or folded; (9) *kural*, very small and misshapen; (10) *thool*, "seed." The sizing is effected by passing them through a succession of brass cullenders, called "baskets," having the size and shape of large saucers. There are 10–12 of these. The first is perforated with 20 holes, and the pearls which do not pass through it by shaking are called "of the 20th basket." The succeeding baskets have 30, 50, 80, 100, 200, 400, 600, 800, 1000, each giving the name corresponding with its number of holes to the pearls that do not pass through. After sizing, the pearls are weighed, and their value is then expressed at a rate "per *chow*," which term embraces all the qualities which have been estimated.

China possesses a pearl-mussel fishery near Pakhoi. The grounds are divided into four districts, lying between the S. coast of the Pakhoi Peninsula, the island of Weichow, and the Leichow Peninsula. The fishery takes place every 10–15 years; the last (1875) gave a value of 30,000 *taels* (of 6*s.*). Cochin China has an extensive commerce in mother-of-pearl, obtained mostly in the Bay of Tirwar. On the N. coast of Japan, is a considerable fishery of *awabi* (*Haliotis gigantea*), a mussel affording mother-of-pearl, which is much esteemed by the Japanese and Chinese. The Philippine Islands produce large quantities of mother-of-pearl. The exports were 155 tons, value 17,402*l.*, in 1877, and 152 tons, 17,073*l.*, in 1878; in 1879, 2198 *piculs* (of 139½ lb.), value 16,045*l.*, were shipped to the Straits Settlements and India. The whole extensive range from the Tawi-Tawi Islands and Sulu, as far as Baselan, is one vast continued bed of pearl-mussels, principally of the *behoren* or mother-of-pearl species, called *tipi* by the natives, but there is also a large area occupied by the Ceylon oyster, termed *kapis* by the Malays. The principal banks of the latter are found in Maludu Bay. The fishery is carried on by both Chinese and Malays. The Sulu fishery, about Tawi-Tawi, is described by Moore as being superior in extent and productiveness to all others. The Sulu pearls have always been celebrated as the most valuable produced; the mother-of-pearl shell is distinguished by the yellow colour of the border and back, rendering it unfit for some purposes. Some 2500–3000 cwt. are sold annually. Labuan is the chief mart for the Sulu product; in 1868, the value was 11,554*l.*; in 1870, it had fallen to 5686*l.*, and still lower in 1878. A few inferior pearls are obtained from a small oyster in Borneo. Macassar is the market for the pearl-mussels found by the natives of the Bayos. In Kau Bay, between the N. and N.-E. peninsulas of the island of Halmahera, are pearl-banks belonging to the Sultan of Ternate. The sea about the Aru Islands affords both pearls and mother-of-pearl, which are taken to Dobbo. The pearl-banks on the W. side are rich, but have hitherto been neglected. The head-quarters of the pearl-fishery is the Blakong Tanah, on the E. side of the islands, facing New Guinea. This is the most important pearl-fishery in the whole Archipelago. In 1860, the product was 2500 *piculs* (of 135½ lb.), value 190,000 *fr.*, and 20,000 *fr.* worth of pearls. The island of Timor has pearl-banks, but the yield is trifling.

The great Queensland pearl-fishery in Torres Straits is mostly in the hands of Sydney capitalists. It is carried on by boats, with Malay divers, in water of 4–6 fathoms. The pearl-mussels of Torres Straits have a weight of 3–6 lb., and even 10 lb. The weight and worth of the pearl-mussels exported from Queensland have been as follows:—1874: 2 lb., 12*l.*; 1875: 112 cwt., 799*l.*; 1876: 2886 cwt., 15,665*l.*; 1877: 7768 cwt., 48,723*l.*; 1878: 9530 cwt., 54,149*l.* The official statistics from the station in Thursday Island for the year 1st May, 1878–30th April, 1879, were:—Living pearl-mussels, 425 tons, 1½ cwt.; dead pearl-mussels, 4 tons, 2 cwt.; pearls, 130*l.* worth. The value of the mussel-shell at 130*l.* a ton is 112,320*l.* The pearl-fisheries of the N.-W. coast of Australia give extensive employment, the divers being Malays from the Dutch settlements, and natives; the diving is carried on from the end of September to the end of March. The extent of these banks is probably far from being defined as yet. A vessel engaged in pearling in King Sound, in 1879, got 21 tons of shells in 25 days; the banks doubtless exist between Beagle and Collier Bays, and there is reason to hope that they reach as far north as the Gulf of Carpentaria. The fishing is carried on solely for the value of the mother-of-pearl shell (*Meleagrina margaritifera*), but it also yields a number of pearls, some having a high worth. The shells are of the best kind known, weighing 1½–6 lb. a pair. They are subject to an export duty of 4*l.* a ton. A distinct fishery is carried on in Shark's Bay (W. Australia), particularly on the banks in Useless Harbour. The shell here found is the true pearl-mussel (*Avicula margaritifera*). The shells are very thin, with a beautiful pearly inner surface; till quite recently, they were considered valueless, on account of their thinness, but quantities are now being sent to Havre at a most remunerative price. The pearls themselves are the main object of search, and large numbers must be found; but as there is no duty of any kind levied upon them, statistics are wanting. They have a brilliant lustre, but seldom exceed the size of a pea. The capture of the molluscs is effected by dragging iron-wire dredges over the banks in shallow water. The shells are heaped up ashore for the occupants to rot, when they are easily opened and searched. The pearl-fisheries of W. Australia possess a considerable and growing importance. In 1874, the total ascertained value of the exports of mother-of-pearl was 58,928*l.*, and of pearls, 6000*l.*; the exports of the former in 1876 were 240 tons to London, and 67 tons to Singapore, the price fluctuating at about 250–280*l.* a ton. The discovery of molluscs yielding mother-of-pearl and pearls in Oakley Creek, New Zealand, has been reported.

Diving for pearl is one of the chief occupations of both sexes of natives in the islands of the S. Pacific. The mollusc here sought is the mother-of-pearl-yielding mussel, which inhabits the interior lagoons of the great coral *atolls*. It frequents the clean growing coral, where it can attach itself free from sand or drift, and where there is considerable influx and efflux of tide. It is also to be found in great numbers under the breakers that beat upon the outer reefs, and probably at greater depths in the sea beyond. The animals are gregarious, and love to congregate in large piles, firmly attached to one another. Unfavourable conditions will cause them to migrate *en masse* for a short distance. The attachment to the rock is effected by means of a "cable" springing from the body of the mollusc, and passing through an orifice between the shells at the hinge. During life, the colour of this cable is dark-green to golden-bronze, and a similar degree of brilliancy pertains to the two flat surfaces at the back of the hinge; the exact degree and shade of these colours are said to indicate the presence or absence of pearls within the shell, with such a degree of certainty that experienced fishers will select 75 per cent. of the pearl-containing mussels from a boat-load by this sign alone. The shell comes to maturity in about seven years, at which time, its average weight is 1 lb. empty; the usual size is 10 in. across, sometimes reaching 18 in. When mature, the creature detaches itself from the rock, opens, dies, decays, and the shell becomes coated with coral and parasites, and loses all value, while any loose pearls contained in the shell fall out and are lost. The animals have several enemies, one of the worst being a centipede-like creature which infests stagnant lagoons, and enters the shells and devours the occupants. Almost all well-grown mussels are troubled with lobster-shaped parasites, about the size of shrimps, which inhabit and breed in the mussel-shells.

The shells are secured individually by divers. When landed, they are generally separated into two piles, consisting of those which are supposed to contain pearls and those which are not. The shells are opened by flexible steel-bladed knives; a skilful hand will open one ton of shells per diem, without missing any pearls there may be. The emptied shells (mother-of-pearl) are at once placed in the shade, to preserve their colours. The animals are eaten in times of great scarcity. Pearls, when present, are usually lodged in the muscle whence the cable springs, which, being transparent, easily reveals their presence. When many are found in one shell, they are commonly small and ill-formed. Other pearls occur sometimes loose in the shell; these are always of very fine quality, perfectly round, and often large. Not more than one mussel in a thousand contains such pearls, but when they are present, they are frequently lost by the natives through carelessness in opening. Fine, calm weather is most favourable to the fishing, but not indispensable. No accessory or apparatus of any kind is used by the divers; but they rub their bodies with oil, to avoid blistering by the sun. They can remain under water 1–2 minutes or more, and are able to bring up shell from 20 fathoms. Few shells are got from this depth, but those are exceptionally fine. Many fisheries now supposed to be exhausted still contain great riches in the deeper water; and many lagoons that have afforded nothing in the shallow water will repay search at greater depths. Taking all things into consideration, the cost of raising mother-of-pearl shell in these islands is about 5–6*l.* a ton.

The pearl-fishery of the S. Pacific is carried on chiefly in the Tuamotu [Pomotou, or Low] Archipelago, in the Gambier Islands, and in the Navigator's Islands. Very many other localities are partially or totally neglected. Thus the island of Manihiki, which afforded over 100 tons of shell in 18 months, some 20 years ago, has not been fished since; and the lagoon of Hogolen is known to contain an immense bank of pearl-mussels. The Tuamotus are said to have yielded altogether some 25,000 tons of mother-of-pearl, valued at over 1,000,000*l.* Almost the whole production goes to Tahiti for export. In 1873, the total shipments were estimated to amount to 2000 tons of shells and 200,000 *fr.* worth of pearls. In 1878, Tahiti exported 591 tons of shells, value 35,460*l.*, and 6000*l.* worth of pearls; in 1879, 470 tons of shells, value 28,200*l.*, and 4000*l.* worth of pearls. The export duty of 32*s.* a ton on shells, which was imposed in 1875, was removed in 1878; this fact partly accounts for the increased export in 1878. The classification of pearls in the Pacific Islands is as follows:—(1) Those of regular form and without faults: value, 3*s.* per $\frac{1}{10}$ *grm.*, those weighing $1\frac{1}{2}$–$2\frac{1}{2}$ *grm.*, 100–140*l.*; (2) round, white, and of good lustre: value, 30 *grm.* containing 800 pearls, 4*l.*, the same weight in 50 pearls, 60*l.*; (3) irregular form, not free from faults or spots: value, 30 *grm.*, 3–4*l.*, according to degree of tarnish by black blemishes and dulness; (4) knots of pearl, which have adhered to the shell: value, 30 *grm.*, 30–40*s.*, according to regularity and brilliancy; (5) seed-pearls, 2–3*l.* a lb. Mother-of-pearl brings 3–6*d.* a lb. The chief markets for Pacific pearls are Hamburg, Amsterdam, London, and St. Petersburg.

Besides the pearl-mussel, a species of large clam is found in the lagoons of many of the Pacific Islands, affording pearls of unusual value. They are of two kinds, and are locally called *paahua* or *tridachna*; one grows chiefly on the solid coral, and does not attain so great size as the other, which is found not only on the hard reef, but bound to loose rocks, or lodged upon the sandy bottom. The latter attains enormous proportions, and is the kind which yields pearls. These are found in the body of the animal, and are so common that 100 may be gathered in a day's fishing, but they are generally of irregular shape and quite opaque; they are never sought after by the fishermen, and valuable ones are rare, but their systematic search would probably be highly remunerative. Yet another pearl-yielding mollusc inhabits these seas, with a shell like that of an oyster. It is always firmly attached to the rock, and is found singly, so that it is scarce; but it affords perfectly round, lustrous, golden-coloured pearls, about as large as peas.

The Central American pearl-fisheries lie on both the Atlantic and Pacific sides. They occur in the Bay of Panama, about the Pearl Islands, of which St. Joseph is the most important, whence 800–1000 tons of shell have been taken annually. In 1869, we imported pearls to the value of about 40,000*l.* from New Granada, the Atlantic ports of America, and St. Thomas; and the average annual value of the Panama fishery has been estimated at about 25,000*l.* In the lower part of the Bay of Mulege, in the Gulf of California, near Los Coyetes, pearls have been found of great value; and it is generally believed that a series of beds extend from the Gulf of Darien to the Gulf of California. In the latter, and along the shores of Central Mexico and Costa Rica, pearl-fishing has long been a lucrative occupation. There is great variety in the quality of the shells from different localities. The chief fishery on the Mexican coast is between Mulege and Cape San Lucas, and in a lesser degree around the Islas tres Marias, and in the neighbourhood of Acapulco. The molluscs here met with are the *concha nacar* or mother-of-pearl mussel (*Meleagrina margaritifera*), and ear-shells (*Haliotis rufescens*). The fishery is carried on during July–October, wind and cold preventing it at other seasons. The use of diving apparatus is coming largely into vogue. The mother-of-pearl found in the Gulf of California is white, with blue-black or yellow bands, and 3–6 in. across. The size and number have much decreased of late years, on account of reckless fishing, without giving time for the beds to recover; also, it is thought, from the damage done to young molluscs by the heavily-weighted boots of the divers. It has recently been determined to suspend operations, and open the fishery only once in every four years. The Californian shells go almost exclusively to Hamburg, whence Austria, France, and England draw their supplies. The pearls go mostly to Paris, but also to Frankfort-on-Maine and Hamburg. The total Californian fishery is reckoned to produce 6000–7000 cwt. of mother-of-pearl annually. The exports of mother-of-pearl from Costa Rica were 2042 lb. in 1875, 4425 lb. in 1876, 42,446 lb. in 1877, 6750 lb. in 1878, and 3549 lb. in 1879; the value rose from 2*c.* to 10*c.* a lb. Panama, in 1879, shipped 7000*l.* worth of pearls to the United States. Guayaquil shipped at the rate of 13–14 tons yearly of mother-of-pearl about 1871.

In the Bahamas, conch-fishing is an important industry. The only species affording pearl is the common pink conch (*Strombus gigas*). The pearls taken from under its apron are pink, yellow, or black, the first-named alone having any value. They possess a delicate pink tint, and are often beautifully waterlined, which, with their size and colour, determines their worth. They are readily saleable in Nassau (Bahamas), at figures occasionally reaching 20*l.* The value of the total annual export is estimated at 10,000*l.*

Ohio, one of the States of the American Union, is remarkable for an extensive fishery of a kind of river-pearl, in the Little Miami river, Warren County. The fishing season lasts from June till October. Men and boys wade over the banks in the river, and raise the shells with their feet, so as to avoid putting the head under water. The shells are opened with a knife, and in about one case out of 150, pearls—sometimes to the number of three—are found between the shell and the membrane that lines it.

Qualities, Values, and Commerce.—The qualities of pearls and mother-of-pearl vary widely. The best pearls are of a clear, bright whiteness, smooth and glossy, and free from spot or stain. The globular form is most generally esteemed, but pear-shaped ones of large size make handsome earrings. Pearls of dark colour are in little favour. The value, other conditions being equal, increases geometrically with the size. Thus a pearl of 3 gr. is worth about 19*s.*; 4 gr., 32*s.*; 5 gr., 47*s.*; 6 gr., 75*s.*; 8 gr., 114*s.*; 10 gr., 11*l.*; 12 gr., 16*l.*; 14 gr., 20*l.*; 16 gr., 30*l.*; 18 gr., 40*l.*; 20 gr., 50*l.*; 24 gr., 72*l.*; 30 gr., 100*l.* When two or more pearls possess identity of form, size, colour, &c., they assume a fancy value beyond all rules. Mother-of-pearl owes its beauty to the minute corrugations of its surface, which cause the much-admired iridescence. The shells, as imported, are of various sizes and values. The smallest are Panama, weighing about ½ lb. the single valve; Bombay and Egyptian weigh about ¾ lb.; black-edged South Sea, 1 lb.; Manila, Singapore, and Australian, 1¼–3 lb. The medium and small shells, being cleanest, bring higher rates in comparison with the larger. The approximate London market values are:—Panama, 60–85*s.* a cwt.; black-edged S. Sea, 65–130*s.*; Bombay and Egypt, 95*s.*–132*s.* 6*d.*; Manila, 135–160*s.*; Australian, 130–220*s.* Pearls are used exclusively for jewellery in Europe and America. Mother-of-pearl has very wide applications for ornamental purposes, such as fans, studs, buttons (see p. 558), card-cases, and multifarious toilet articles, as well as in cabinet-making, inlaying, and papier-maché work. In 1870 (the latest detailed Return), we imported 26,197 cwt. of mother-of-pearl, value 76,489*l.*, and 16,675*l.* worth of pearls. In the ten years ending 1876, France imported 1,376,132 *kilo.* of mother-of-pearl, value 3,159,943 *fr.*, and 118,078 *grm.* of pearls, value 2,007,333 *fr.*; France also now imports about 125,000 *kilo.* annually of ear-shells (*Haliotis*). The imports of mother-of-pearl at Hamburg were 7600 cwt. in 1875, 600 cwt. in 1876, and 3300 cwt. in 1877.

A good remedy against the liability which pearls manifest of losing their brilliancy is to keep them in magnesia. An artificial imitation of pearl is largely made on the Continent, the essential ingredient being guanine, a silvery mucus found on the scales of *Lenciscus alburnus*, which is incorporated with wax, and may be either bored and strung as pearls, or spread to resemble mother-of-pearl. (See also Celluloid, p. 615, for artificial pearl-making).

Coral (Fr., *Corail*; Ger., *Koralle*).—There is still great ignorance on many important points relating to the production of coral. The little that is known leads to the belief that its growth is rapid; that its development is simple; that it accommodates itself to very varied circumstances; and that detached fragments from the bunch or principal stem have vitality, and will attach themselves to fixed substances for continuing their development and forming new trunks. But at what age coral attains its largest size; how long it takes for an exhausted coral bank to recover itself; at what period the eggs are laid; how the products are disseminated; at what period the budding takes place, and how long it lasts: these questions, on which rests the progress of the coral fishery, are as yet unsolved.

Coral stem is divisible into two distinct parts: a central axis, hard and brittle, which is the part used in commerce; and a soft covering or epidermis, which easily yields to the nail when fresh, but is friable when dry.

Coral of various kinds is met with in shops, and sold under the names of "white coral" (*Oculina* [*Madrepora*] *virginea*), "brainstone coral" (*Mendrina cerebriformis*), "black coral" (*G. Antipathes*), and "organ-pipe coral" (*Tubipora musica*), named from the arrangement of its cylindrical dark-crimson tubes. Occasionally "red coral" is found without any colouring matter. Black coral takes a fine polish, and is fashioned into beads, and mouth-pieces for cigars. The dull white is not quite so hard, and not polishing well, is sold cheaper. It is often deteriorated by being worm-eaten.

Coral has the hardness and brilliancy of agate; it polishes like gems, and shines like garnet, with the tints of the ruby. The larger branches are used for carving. Large, perfect, well-shaped beads are by far the most valuable form of coral, and these have greatly increased in estimation of late years. Many of the finest are sent to China, while tons of what may be called "worm-eaten" beads, which would not find favour in Europe, go to India, where they are esteemed.

Much of the coral is wasted in the process of conversion into uniform well-shaped beads, and this, of course, adds greatly to the cost. The manufacturing processes consist of three different operations—cutting, piercing, and rounding; these are principally executed by the females of the Val du Bisagno, in Italy.

The principal commercial varieties of coral distinguished are:—red, subdivided into deep-crimson red, pale-red, and vermilion (rare); black; clear-white; and dull-white (most common). The delicate rose or flesh-coloured, which is the most prized, is sold at very high prices, as it is entirely a fancy article. Red coral is sometimes classified into twelve shades, besides white and pink; sometimes into five commercial grades:—(1) froth of blood; (2) flower of blood; (3, 4, 5) blood of first, second, and third qualities.

Coral is valued according to its bulk, colour, soundness, and freedom from defects. Certain rare kinds, of pale tints, are worth twenty times their weight in pure gold. The ornamental applications of coral are very varied.

All corals possess a certain industrial value as sources of lime for building and manurial purposes; but the red or precious sort (*Corallium rubrum*) is the only one forming an important article of commerce, and to it the following remarks apply.

The localities affording it are the N.-E. and S. shores of the Mediterranean, the coasts of the chief islands in that sea, and a portion of the E. shore of the Adriatic. It usually lies at 2–10 miles from the land, and in water of 30–130 fathoms, finding its most favourable conditions in 80 fathoms. It is said to attain greater perfection in the E. than in the S., and to be rarely found in a W. and never in a N. aspect. It occurs attached to rocks embedded in a muddy sea-bottom, where it flourishes better than in clear or sandy beds.

The headquarters of the Italian coral-fishery are: From the island of Elba to the coast of the mainland by Cecina and Spezia; the so-called *secche corallere* grounds in the Bay of Naples; Nico; the Sorrent peninsula; near Nisida and Cape Miseno, E. of the island of Ischia: both coasts of Calabria; the islands between Sicily and Calabria; near Sciacca, and the island of Pantellaria; the Tizzano ground between Corsica and Sardinia; around Sardinia the grounds of Alghero, Longo Sardo, Bosa, Castelsardo, Isola di S. Pietro, S. Antioco, Maddalena and Caprera, from the Straits of Bonifacio, along the Corsican coast to Cape Corso; thence into French territory, from the Iles de Hyères to Cape Couronne; in the Gulf of Rosas and on the banks of Cape Tarsuela di Mongril, to the limit of the gulf in Catalonia. The Italian coral-fleet in 1869 numbered 200 large and 260 small boats, the crews were a total of 4000, and the yield was 160,000 *kilo.* of coral, valued at 9,600,000 *lire* (of 9½*d.*). Since then, the industry has much increased, if the statement be true that during last year (1880) some 500 boats from Torre del Greco alone were on the Sciacca bank, besides an equal number from four other ports. The annual value of the Sardinian coral is estimated at 60,000*l.*, giving a profit of 13,000*l.*; the exports are 200,000–250,000 lb. a year. The fishery lasts from March till October.

The barks employed are stout craft, rigged with a great lateen sail and a jib or stay-sail. The apparatus, or "engine," as it is called, for detaching the coral from the rocks and hauling it aboard, consists of a huge wooden cross, heavily weighted, and furnished with numerous, sack-like, meshed lines. This implement is thrown overboard in likely spots, trailed astern, and drawn up by means of a capstan. Diving-bells and vessels suited for submarine navigation have been proposed and tried as substitutes for this crude fashion, but have not come into use. A large boat may collect 650–850 lb. of coral in a season.

It has been estimated that the Sciacca bank yielded, between the 1st June and 31st August 1875, 264,000 lb. of coral, which sold for at least 92,400*l.* The bank was said to be 550 yd. long and about 30 yd. thick. Statistics concerning the Italian coral industry, published in 1871, gave the number of boats as 300 from Torre del Greco, 60 from Leghorn, and 100 from Liguria and Sardinia; the number of persons employed, 6000; the catch for each boat necessary to defray all cost, 200 *kilo.* at an average value of 48*s.*, or 480*l.*; and the receipts of coral at Italian ports, 160,000 *kilo.*, value 380,000*l.* The Alghero banks in 1873 employed 239 boats, which gathered 25,384 *kilo.* of red coral, and 9536 of white, total value, 160,080*l.*; in 1874, 159 boats took 12,260 *kilo.* of red and 6758 of white, total value, 93,960*l.* The Cagliari fishery occupied 180 boats in 1875, whose take was estimated at below 1,000,000 *fr.*

The coral-fisheries of Austro-Hungary are exclusively on the coast of Dalmatia, the island of Zlasin being the centre. Each boat obtains some 80–100 lb. yearly, the total value being placed at 6000–10,000 florins (of 2*s.*). The pale-red and very thick Dalmatian coral is much esteemed.

Spanish fishermen collect annually about 25,000 lb. of coral, worth 20,000*l.*, around the Cape Verde Islands.

The coral-banks on the Algerian coast lie in a depth of 12½–100 fathoms, in the neighbourhood of La Calle, the Gulf of Bona, Cap de Fer, Djidjelly, Bougie, Cape Matifu, Tenes, Cape Ferrat, Cape Falcon, Habibas Island, and Cape Figalo. About ⅓–½ of the boats engaged are Italian; they are stout sailing-craft of 6–14 tons, with a crew of 10–12, while smaller boats with 4–6 hands work the coast-fisheries. The total number of boats in the years 1868–76 varied between 202 and 388. Foreign vessels pay 800 *fr.* for a licence to fish, except Italian, which pay only 40 *fr.* The yearly product is stated by the fishermen at 30,000–40,000 *kilo.*; and the total value of the Algerian and Tunisian fisheries is computed at 2,500,000 *fr.* annually. The value of the Algerian exports is placed at 80,000*l.* per annum; the quantity in 1878 was 34,288 *kilo.*, in 1879, 17,876 *kilo.*, value 536,280 *fr.* Each reef is divided into tenths, one of which is worked in a year; thus a period of 10 years intervenes between the harvests from the same spot. On the coast of Tunis, between Biserte and Tabarque, are annually obtained some 25 metric quintals (of 1·96 cwt.) of coral, varying in value from 80 to 90 *fr.* a *kilo.* The ground is worked chiefly by Italian and Greek boats, and the product is taken to Torre del Greco and Livorno.

The coral of the Red Sea is not of the valuable kind. A rich bank is said to have been discovered on the Japanese coast, whose product possesses the peculiarity of being white in the centre and at all the lateral points; but it is apt to scale or break off.

In the N. African fisheries, coral is divided into the following classes:—(*a*) "Dead" or "rotten," including the roots adhering to the rock, and covered with vegetable and mineral incrustations, worth 5–20 *fr.* a *kilo.*; (*b*) "black," which gives a polished black surface, suited for mourning jewellery, and fetches 12–15 *fr.* a *kilo.*; (*c*) "in case," or coral which has been assorted and cleaned when taken from the sea, consisting of branches of all sizes, and worth 45–70 *fr.* a *kilo.*; (*d*) "choice," or finest, selected, large branches, valued at 400–500 *fr.* a *kilo.*

The imports of coral into the United Kingdom in 1870 (the latest specific Return) were:—1600 lb. of "fragments," 418 lb. of "whole," 652 lb. of "*negligées*," and 958 lb. of "beads," the total being 3628 lb., value 14,878*l.*; the figures fluctuate immensely, having been 8106 lb. in 1868, 1087 lb. in 1863, and 16,385 lb. in 1861. These statements take no account of the quantities of valuable coral brought in passengers' luggage. In the 10 years ending 1876, France imported 21,596 *kilo.* of rough coral, value, 1,890,356 *fr.*, and 14,553 *kilo.* of worked, unmounted coral, value 5,078,062 *fr.* British India, in 1879, imported 79,643 lb. of real coral, value 81,862*l.* Quantities are exported from India into Thibet, in pierced grains of round or oval form, the darkest colours being most esteemed. China imports various kinds from Singapore, Sumatra, and the Samar Islands, black being preferred.

An imitation of coral for ornamental work may be made by dipping twigs in a mixture composed of 4 parts of rosin, 3 of bees-wax, and 2 of vermilion, melted together.

The London market value of coral fluctuates very widely. The finest rose-pink specimens range between 80*l.* and 120*l.* an oz.; small pieces of ordinary red are worth about 2*l.* an oz.; while small fragments (*collette*) for necklaces bring about 5*s.* an oz.

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PERFUMES (FR., *Parfums*; GER., *Wohlgerüche, Düfte*).

The term "perfumes" is applied to those substances emitting an agreeable odour which are used about the person, the dress, and the dwelling. Besides the gratification of the senses derived from the employment of perfumes, many of the latter are credited with actual disinfecting properties, and are therefore valuable from a hygienic point of view. All the essential oils of plants are more or less powerfully antiseptic, and the culture of strongly fragrant flowers is recommended as a means of counteracting the miasma of undrained swamps.

Perfumes may be divided into two main classes—crude and prepared. Crude perfumes comprise the aromatic substances derived from the animal and vegetable kingdoms. Animal perfumes occur almost exclusively as glandular secretions, and enter into commerce in their natural state. Vegetable perfumes are mostly extracted from the flowers or herbs as essential oils, which are described on pp. 1415–33. Some few plant-odours have the form of balsams, and will be noticed in the article on Resinous Substances. The crude perfumes remaining for description in the present article are those of animal origin, and the few aromatic woods, roots, and fruits which are traded and used in their original condition. Prepared perfumes embrace the numerous extracts or essences, pastilles and ribbons, incenses and satchet powders, waters and vinegars, and nosegays or bouquets.

CRUDE PERFUMES.

Acorus Calamus.—See p. 190.

Agar, Agila, Akyaw, Calambak, Eagle-wood, Kayugaru, or Lignum-aloes.—This curious product is obtained chiefly from the Mergui Archipelago, also from the islands in the Gulf of Cambodia, and from Sumatra. It has been described as consisting of lumps of consolidated aromatic resin, found embedded in the trunk of certain trees, but should rather be considered as diseased wood whose tissues are impregnated with the resin. The latter is found in all parts of the trunk, most frequently in the alburnum or sap-wood, but only where decay has followed intentional or accidental injury. This leads to the inference that the supply might be regulated and increased by a systematic wounding of the trees; it would also appear that the resin is a product of the oxidation of the essential oil contained in the wood, which circumstance might be availed of to artificially augment the yield. Botanists consider it to be produced only by *Aquilaria Agallochum*, but native collectors in Burma state that it is furnished by two kinds of tree, though the substance does not differ. It occurs in very small quantity, and is altogether absent from 19 trees out of 20; the wood-cutters often destroy several trees before finding a particle of it, and it is estimated that some 8000 trees are yearly cut down in the Mergui Archipelago. This is rapidly causing the extermination of the species in those islands, and has led to its attempted cultivation in S. Tenasserim, where 200 seedlings have been planted out. The greater part of the article collected is sent to China, viâ Penang and Singapore, small pieces being used for torches, incense, and medicine. The wood is also cut into fragments, placed in water in a copper vessel, and boiled; from this decoction, the perfume is distilled, and is known as "agar-attar;" it is exported from Burma to Calcutta, for despatch to Arabia and Turkey, and is in high esteem throughout the East. The test of the quality of the resinous compound is that it should melt in the fire like wax, meantime emitting an agreeable odour. The approximate local values per *picul* (of 133⅓ lb.) are:—1st quality (Sumatra), 40*l.* 16*s.* 8*d.*; 2nd quality (Malacca), 25*l.* 10*s.*; 3rd quality (Malacca), 3*l.* 2*s.* 6*d.*

Ambergris (Fr., *Ambre gris*; Ger., *Amber*, *Ambra*).—Ambergris is probably a biliary calculus, or mass of undigested and biliary matters, obtained from the stomach of the spermaceti-whale (*Physeter macrocephalus*), and possibly some other species. It is generally found, after having been ejected by the animal, floating on the surface of the sea. Its presence in the animal is said to be always an accompaniment (either cause or effect) of disease. It occurs in amorphous masses, usually only a few oz. in weight, yet concretions weighing 150–300 lb. have been found. Its general colour is greyish-white, with bands of brown or black, as if marking the addition of layers. It has a waxy texture, pungent, agreeable odour, and fatty flavour; it is lighter than water, melts at 60° (140° F.), dissolves readily in absolute alcohol, ether, and both fatty and essential oils; it contains 85 per cent. of an aromatic substance called "ambreine," extracted by digestion with alcohol of 0·827 sp. gr., filtering the solution, and leaving it to spontaneous evaporation; the ambreine then forms delicate white tufts, converted into ambreic acid by the action of nitric acid. Ambergris is sought after in all the fisheries frequented by the sperm-whale (see Spermaceti, p. 1371). Formerly considerable pieces have been found on the W. coast of Ireland—Sligo, Mayo, Kerry, and Isle of Arran. The exports of ambergris from Morocco are extensive, the supply being contributed by whales cast up on the W. coast. The exports were 27 lb., value 600*l.*, in 1868; 65 lb., 1300*l.*, in 1869; 100 lb., 2000*l.*, in 1870; and 18 lb., 360*l.*, in 1873. It is occasionally found on the coasts of some of the Bahamas; the values of the shipments thence were 10*l.* in 1875, 11*l.* in 1877, 1014*l.* in 1878, and 737*l.* in 1879. In 1869, France imported more than 7000*l.* worth of ambergris from Madagascar and Mayotte. The American whale-fisheries produced 15 lb., value 1454*l.*, in 1876; 132 lb., 21,000*l.*, in 1878; and 81 lb., 8781*l.*, in 1879. Ambergris is valued in perfumery less for its own fragrance than for the permanence it gives to compounds into which it enters, by reason of its slight volatility, insolubility in weak alkaline lyes, and slow decomposition.

Castor.—Castor or castoreum has been noticed under Drugs (see p. 798), as it possesses almost as great importance in medicine as in perfumery. Two or three kinds are distinguished, differing considerably in chemical composition and in odour. The Canadian has the weaker odour, resembling that of old willow-bark; the Siberian or European is much stronger, and recalls that of birch-oil. The pear-shaped sac occurs the most frequently, especially in Canadian. Egg-shaped sacs are suspected by the buyer as containing more carbonate of lime. Adulteration may be detected by dividing the sac, either by breaking or cutting, when the membranes become visible if it is genuine. The main commercial distinction lies between the Russian (Siberian) and Canadian (American), the Bavarian being considered nearly equal to Russian. In a dry state, castor manifests little odour, but it is developed remarkably by infusion in spirit. It is used in perfumery to give permanency to other odours, being rarely esteemed itself. The Hudson's Bay Co. import some 1000–5000 lb. yearly.

Civet (Fr., *Civette*; Ger., *Zibeth*).—Civet is another of the odorous animal secretions contained in glandular receptacles near the genital organs. The true civet cat (*Viverra Civetta*) inhabits portions of the African continent, from Guinea and Senegal to Abyssinia. The Asiatic species is *V. Zibetha*, which is found in many parts of India, the Moluccas, and other island groups. *V. Rasse* is peculiar to Java, where its perfume is largely made use of. In the Moluccas, Wallace found *V. tangalunga*, inhabiting both Batchian and Bouru, and probably some of the other islands. He supposes it to have been introduced accidentally, as it is often captured by the Malays, who procure civet from it, and it is a restless and untamable animal likely to escape. The same species is common in the Philippines, and in all the large islands of the Indo-Malay region. Formerly numbers of *V. Civetta* were kept in confinement at Amsterdam; and a similar collection of *V. Zibetha* is, or was, maintained at Travancore. The aromatic secretion was removed from the pouch by a little spoon about twice weekly, the animal being meanwhile confined in a crib. About 1 dr. was obtained at a time. Flesh, but particularly fish, is the favourite food in confinement. The secretion of *V. Zibetha*, which is the chief kind in British commerce, is prepared for market by spreading on leaves of the pepper-vine, to free it from loose hairs. Civet, when good, has a clear yellowish or brownish colour, and a buttery consistence; it is frequently adulterated with butter and lard. Its undiluted odour is repugnant, but in infinitesimal proportion it is agreeable. Macerated in spirit, it is used chiefly as a fixing ingredient of compound scents, more largely in France than in England, where musk is preferred. The fragrant secretions of the genet or Spanish cat (*V. Genetta*) and of *V. pallida* do not seem to have been utilized.

Musk (Fr., *Musc*, *Graine d'ambrette*; Ger., *Moschus*, *Bizam*).—In common usage, the term "musk" is applied in compound names to a number of products of both animals and vegetables. Foremost is the musk-deer (*Moschus moschatus*), which will be described at length in this article.

The musk-ox (*Ovis moschatus*) affords a valuable skin (see Skins), but its odour is not utilized. The musk-rat or musquash (*Fiber zibethicus*) is provided with preputial follicles containing a substance of musk-like odour, but is valued only for its pelt (see Fur, p. 1032). The musk-rat of India (*Sorex indicus*) diffuses a most powerful odour of musk, as also does the *pilori* of the Antilles. Several Brazilian monkeys are said to emit an odour of musk. The alligator of Central America carries an odoriferous substance in the axillary glands and under the jaw, which, 200 years ago, was extracted and used as a perfume. The musk-glands of the crocodile are similarly utilized by the natives of some parts of Africa. In W. Australia, the aborigines obtain musk from the musk-duck (*Biziura lobata*). Several longicorn beetles exhale a musky odour, notably the British musk-beetle (*Callichroma moschata*); and somewhat similar perfumes pervade some species of *Cerambyx*. The most recent addition to animal musks, or substitutes for musk, has been made by Dr. Bertherand, in the droppings of the gazelle (*Gazella Dorcas*), common in the Sahara. The dried excrement is said to yield to rectified spirit 7 per cent. of a mixture containing a resinous musk-like principle, benzoic acid, a biliary acid, and colouring matter.

Among vegetable musks, may be mentioned the musk-plant proper (*Mimulus moschatus*), common in window-culture. The musk-wood of the Guianas and W. Indies (*Guarea trichilioides*, and other species) smells strongly of musk, the odour being greatest in the bark, which may be used as a perfume. Musk-like fragrance is also exhibited by *Erodium moschatum*, by the sumbul or musk-root (see Drugs, p. 826), by the spikenard of the ancients (*Nardostachys Jatamansi*), by the tuberous moschatel (*Adoxa Moschatellina*), by the silver-leaved musk-tree of Tasmania (*Eurybia argophylla*), by the musk-wood of Jamaica (*Moschoxylum Swartzii*, and *Guarea spp.*), and finally by the seeds of *Hibiscus Abelmoschus*, which plant is better known perhaps for its fibre (see p. 962). This last kind is known as musk-seed, and is commercially valuable as a perfume. The plant is cultivated in Martinique, whence its seed is largely exported to France as *ambrette* or *graine d'ambrette*. It is occasionally imported into London, and fetches about 4*s*. a lb.

Despite the large number of products capable of affording more or less of a musk-like odour, the musk-deer remains the one important commercial source of the perfume. This little animal, scarcely larger than a greyhound, is an inhabitant of the Himálayan range. From the first high ridge above the plains, to the limit of forest on the Alpine range, and throughout probably the whole length of the Himálayan chain, this deer may be found on every forest-clad hill above 8000 ft. It inhabits all kinds of forest indiscriminately, from the oaks of the lower hills to the stunted bushes near the limit of vegetation, but exhibiting a preference for birch forests, where the underwood consists chiefly of juniper and white rhododendron. A variety of the musk-deer, if not the same animal, extends its range into the dry and desert region north of the Himálayas. It is of common occurrence on the Tsanpu river in the neighbourhood of Lhasa, but only, it would seem, where the birch grows. It is abundant in Bhutan, and probably (according to R. Lydekker) ranges northward of that district over most of the open country up to Tibet, and thence across or round the Gobi desert into Siberia.

The animal is nocturnal in its habits, and exceedingly shy and agile. In some districts, it is hunted down by dogs; but it is much more commonly snared, by erecting a fence about 3 ft. high and 1 mile or more long, with openings at every 10–15 yd., provided with strong hempen snares, which catch the animal by the leg. Entrapped animals are sometimes destroyed by polecats and other vermin; in such cases, the musk-pod may be torn, and its contents scattered, but not devoured. The pod is found only in the males; and curiously enough, though their dung smells nearly as strongly as the musk itself, no such odour can be detected in the contents of the stomach and bladder, nor in any part of the body. The females are utterly devoid of odour. The pod is placed near the navel, between the flesh and skin, and is composed of several layers of thin skin, having much the appearance of a full craw of a gallinaceous bird. Its interior communicates with the outer air by means of an orifice that will admit the little finger by slight pressure, but it has no visible passage leading inwards. The musk is confined in this pod in grains of irregular roundish or ovoid shape, varying in size from small shot to a bullet, together with some coarse powder. Its colour when fresh is dark reddish-brown, becoming nearly black when removed and kept. In the cold season, the grains are firm, hard, and nearly dry; in hot weather, they become damp and soft. The pod is fully developed long before birth, indeed it is then disproportionately large. For two years, the contents remain as a soft, milky substance, of disagreeable odour. When first it becomes musk, its weight does not exceed $\frac{1}{8}$ oz.; it increases with the animal's growth, and reaches 2 oz. in some individuals, but the average yield from a full-grown animal is 1 oz., and the proportion of immature animals killed will reduce the mean of commercial pods to $\frac{1}{2}$ oz. The odour of the musk of young animals is less strong, but pleasanter than that of old ones. Differences in food, climate, and situation have not been found to affect the quality. Before the age of 3 years, the quantity is not sufficient to be worth extracting; it is greatest during the rutting season. Occasionally the musk appears to be discharged through the orifice in the pod, leaving the latter almost empty. The dealers also extract the grain musk by its means, and replace it by various substances. The size of the orifice may thus indicate in some measure the degree of tampering undergone.

The natives have two methods of preparing the pods. Usually they cut round the pod, and skin the whole belly immediately after the death of the animal. The pod comes away attached to the skin (not unhaired), which is then spread on a heated stone, flesh-side downwards, and thus dried without singeing the hair. The skin shrivels with the heat, and is tied or stitched around the pod, and the whole is hung up in a dry place till quite hard. Sometimes the pod is put into hot oil, instead of being laid on a hot stone. The object in each case is to prevent the subsequent decomposition of the fleshy skin, but the musk cannot fail to suffer much depreciation by the treatment. The best plan is to cut the pod at once from the skin, and allow it to dry in the sun, which it does in a few hours. A substance commonly used by the natives for adulterating musk or filling sham pods is blood, boiled or baked, then dried, beaten to powder, kneaded into paste, and made into coarse and fine grains in imitation of the genuine article. Many other things are similarly used.

Two forms of musk appear in commerce. "Musk in pod" is the material contained in its natural glandular receptacle; "musk in grain" is the material removed from its natural position, and put into bags. The musk in pod varies in appearance, according to whether the pod has or has not been detached from the animal's skin. The three kinds of musk met with in the London market are (1) Tonquin, Chinese, or Tibetan; (2) Assam; (3) Kabardin (Cabardien) or Russian (Siberian). The first is packed in small chests encased with sheet lead, each chest containing 25 paper packages; it is the most highly prized, and most adulterated. The second is packed in bags, stowed into a wooden or tin-plate box, containing about 200 pods, which are of irregular form, and strong but rank odour. The third kind is much inferior, the pods being smaller, and the odour much weaker and less agreeable; it is too poor to bear any adulteration. Recent exports of musk from Chinese ports, stated in *piculs* of 133 $\frac{1}{3}$lb., have been:—Canton, exports to foreign countries, 0·84 *piculs* in 1878, 0·63 in 1879; Hankow, exports and re-exports, 32·32$\frac{5}{16}$ *piculs* in 1878, 31·95 in 1879; Shanghae, total exports and re-exports, 39·20$\frac{13}{16}$ *piculs* in 1879; Ichang, exports, 5·84 *piculs* in 1879. The exports of musk from British India were:—7403 oz., value 10,562*l.* in 1874–5; 5267 oz., 11,782*l.*, in 1875–6; 5020 oz., 11,726*l.*, in 1876–7; 3115 oz., 7904*l.*, in 1877–8; 3444 oz., 6954*l.*, in 1878–9. The distribution of the export in 1878–9 was:—2576 oz. to the United Kingdom, 52 oz. to Malta, 540 oz. to Arabia, 70 oz. to Turkey in Asia, and 206 oz. to other countries.

Musk is employed in perfumery mainly to give permanency to other odours. Its fragrance is much affected and even destroyed by some other bodies; it is considerably altered by camphor and valerian, and is quite destroyed by bitter almonds and powdered ergot.

No serious attempt seems to have been made to domesticate the musk-deer, nor to acclimatize it in other mountain regions. The young taken wild are rather difficult to rear, many of them soon becoming blind, and dying. They eat very little as compared with other ruminants, and feed on various shrubs, grasses, mosses, and roots. Those met with in forest-clad country are much finer than those in open ground.

Nag-kassar.—The flowers of *Calysaccion longifolium* and *Mesua ferrea*, two nearly allied species, are often confounded, and both are collected and sold in the Indian bazars for their fragrance. The first species is a tree, plentiful in S.-W. India and in China; its flower-buds, somewhat resembling cloves, are variously known as *suriga*, *surgiha*, *soohgee-hoo*, and *nag-kassar*, the last being the name under which they have been imported to this country. The second species is much cultivated in Malabar and in Java. The name *nag-kassar* is sometimes spelt *naghas*, *nagasar*, *nagkesur*, or *nag-kushur*. The flowers of both species are largely used in native dyeing in India (see p. 864).

Orange-flowers.—See Neroli-oil, p. 1425.

Orange-zeste.—See Orange-oil, p. 1425.

Orris-root (Fr., *Racine d' Iris*; Ger., *Veilchenwurzel*).—Orris-root is obtained from three species of *Iris*: (1) *I. germanica*, the common "blue flag" of the gardens around London; abundant near Florence and Lucca, ascending to the chestnut region, and found scattered throughout Central and S. Europe, and in Morocco and N. India. (2) *I. pallida*, with much more delicate blue flowers, growing wild in stony places in Istria, and plentiful in the olive-region about Lucca and Florence. (3) *I. florentina*, bearing large white flowers, a native of the Macedonian coast and the S.-W. shores of the Black Sea, notably Hersek, in the Gulf of Ismid, and near Adolia, in Asia Minor; and occurring naturalized in the vicinity of Lucca and Florence. The three species were under cultivation in England at the end of the 16th century. They are all grown for their root in the country about Florence, being known to the peasants of Tuscany indiscriminately as *giaggiolo*. The cultivation is of secondary importance, the plants being placed on the edges of terraces, and on waste stony places contiguous to cultivated ground. The rhizomes are harvested in the autumn of every 3rd year. The plants are dug up early in the autumn, before commencing the next year's growth; the flags (leaves) are cut back, and each root is severed just below the base of the leaves. The head is then replanted, and grows vigorously. It flourishes best in poor soil, and receives no manure. The rhizomes are spread out to dry and ripen in the open air and sunshine, and are peeled and trimmed. Some pieces are bleached by exposure to the fumes of burning sulphur, but such are not available for perfumery purposes. The prepared pieces are classified by the dealers into *scelti* and *in sorte*, and are brought into commerce entire, in fragments (*frantumi*), as parings (*raspature*), as powder (*polvere*), or manufactured into "peas." About Verona, the rhizomes of *I. germanica* (called *giglio celeste* or *selvatico*) are collected and brought into Tregnano and Illasi, distinction being made between the selected long roots (*radice dritta*), the knotty roots (*radice grappo*) used for issue-peas, and the fragments (*scarto*) for perfumery. Some orris-root is exported from Botzen, in S. Tyrol. A sort which has been dried in its outer peel goes by the name of *irisa* in the Indian bazars, and appears occasionally in the London market; it appears to be derived from *I. germanica* [*nepalensis*], cultivated in Kashmir. A low quality of orris-root, the produce of *I. germanica*, is obtained from Morocco. The chief shipments of the root take place from Mogador, Trieste, and Leghorn. The first-named port in 1878 despatched 155 serons, value 410*l.*, to Great Britain, and 27 serons, 65*l.*, to France; total, 364 cwt., 475*l.* In 1876, the total was 834 cwt. France, in 1870, imported a total of about 50 tons of orris-root. The powdered root is largely used in satchets, and its extract in bouquets.

Sandal-wood (Fr., *Bois de Santal citrin*; Ger., *Weisses* [*gelbes*] *Sandelholz*).—The name "sandal-wood" is applied to the aromatic heart-wood of several species of *Santalum*. These are chiefly as follows: (1) *S. album*, a tree of 20–30 ft. in height and 18–36 in. in girth, indigenous to the hilly portions of the Indian peninsula, especially in Mysore, Coimbatore, and N. Canara; found also in the E. Archipelago, particularly Sumba (Chandane or Sandal-wood Island), and Timor; (2) *S. Freycinetianum* and *S. paniculatum* [*pyrularium*] in Hawaii (Sandwich Islands); (3) *S. Yasi*, in the Fiji (Viti) Islands; (4) *S. austro-caledonicum*, in New Caledonia; (5) *S. spicatum* [*latifolium*, *cygnorum*, *Fusanus spicatus*], in W. Australia. The *S. lanceolatum* of N. and E. Australia does not seem to afford a commercial article. The wood of *S. myrtifolium*, in the Madras Presidency, is nearly inodorous. The island of Nossi-bé, on the N.-W. coast of Madagascar, is said to afford some sandal-wood.

The most important of all these sources is the cultivated *S. album* of the Indian reserved forests. The tree occupies patches of a strip of country about 250 miles long, on the eastern slopes of the W. Ghats, just beyond the limits of the Mulnaad or rain-country, as well as a tract further eastward, in the district of Salem and N. Arcot, where it grows from sea-level to 3000 ft. The tree is commonly found in scrub-jungles, and even in open spots in some of the large deciduous forests; but in the plain countries of Mysore, it mostly occurs in hedges and ditches, and on irrigation earthworks. It propagates itself by seeds and suckers, the latter springing up from the long creeping roots wherever these become exposed to the influence of the air, and sometimes developing into good trees at 15 yd. from the parent. It is easily raised from seed, even that which has been stored for months; but transplanted seedlings generally fail. The plantations are now all raised from seed. This should be collected in December–January, and be sown during the early rains in June; 2–3 seeds are dibbled in with 1 capsicum seed, which latter rapidly throws up a plantlet for the shade of the young sandal-trees, and possibly affords them some sustenance. Young sandal-plants flourish best in seed-beds where grass is allowed to grow, as tuber-like processes from their roots prey upon the other growth. Dry, red soils, overlying a stratum of gravel or quartz, are most suitable, the trees maturing in about 20 years; white, strong soils produce trees of stunted growth, mature in 16 years; rich alluvial soils grow very fine trees, requiring 30–40 years to mature, but such trees contain no heart-wood, and are valueless. The maturity of the tree is judged by certain appearances. When the heart-wood is fully formed, the leaves are narrow, and of a dull-green to yellowish-red tint; the small terminal branches are withered, the bark is deeply wrinkled and often moss-grown, and the inner bark, when cut, shows a reddish or yellow instead of white colour. Decay rapidly sets in after the trees have matured.

Mature trees are felled at the end of the year, the branches are lopped off, and the trunk is allowed to lie on the ground for several months, by which time, most of the valueless sap-wood will have been devoured by white ants. Tho heart-wood is then roughly adzed, and sawn into billets 2–2½ ft. long, for conveyance to the government forest depôts. It is again trimmed with the adze, weighed, and classified according to quality. The chips obtained in the first and second trimmings are called respectively "mixed" and "pure." These, as well as the sawdust produced, and the roots of the tree, are subjected to distillation for the sake of their essential oil (see Oils, p. 1430). In Mysore, all sandal-wood trees are the property of the government; the annual exports (shipped from Mangalore) are about 700 tons, value 27,000*l.* In Madras, the culture is free, but is almost entirely restricted to the reserved forests, which produced 15,329 *maunds* (547½ tons) in 1872–3.

The Indian species grows sparingly in the mountains of Timor, and many of the other islands of the E. Archipelago. The heart-wood is brought down in small logs to Dilli, chiefly for export to China, where it is reckoned only ¼–⅓ as valuable as Indian.

W. Australia less than 20 years since exported great quantities of sandal-wood to China. The trees were cut and trimmed in the bush, some 100–150 miles from the ports (Perth or Guildford);

but indiscriminate destruction soon exterminated the trees from accessible regions. The 47,904 cwt. of sandal-wood imported into Singapore from Australia in 1872, for re-shipment to China, was probably mainly of Pacific Islands' production, possibly some portion also from Queensland.

The headquarters of the sandal-wood trees in the Pacific Islands would appear to have been in the S.-W. portion, including New Caledonia, the Loyalty Islands, New Hebrides, Espirito Santo, and some others. Several thousand tons of the wood were shipped at one time; but the tree has now been exterminated from all the well-known islands, with the exception of New Caledonia, where it is under cultivation.

Sandal-wood is little known in Western commerce, but is one of the most important perfumes of the East, where it is chiefly burnt as incense in religious rites. Bombay yearly imports some 650 tons and exports about 400 tons. The chief market for sandal-wood is China, whose imports (in *piculs* of 133⅓ lb.) have recently been as follows:—Chinkiang, 30,818 *piculs* in 1877, 23,719 in 1878, 25,537 in 1879; Hankow, 15,582½ *piculs*, 40,320*l.*, in 1879; Kiukiang, 4378 *piculs* in 1877, 3451 in 1878, 4108 in 1879; Ningpo, 795 *piculs* in 1877, 963 in 1878, 1073 in 1879; Shanghae, 48,325 *piculs* from foreign countries, and 28,219 from Hong Kong and Chinese ports, in 1879; Taiwan, 322⅓ *piculs* in 1879; Wuhu, 5515 *piculs* in 1877, 5319½ in 1878, 7161 in 1879.

Tonquin-, Tonka-, or Tonga-beans.—Tonquin or *gayac* beans are the fragrant seeds of *Dipterix* [*Coumarouna*] *odorata*, a tall tree of Venezuela, the Guianas, and some neighbouring localities, growing best in loamy soil, and easily raised from cuttings. The beans are used whole for perfuming wardrobes, ground for satchet-powders, and in the form of extract. The odoriferous principle, coumarine, is common to the May grass (*Anthoxanthum odoratum*); to the melilot (*Melilotus cæruleus*), the *zieger-kraut* ("curd-herb") of Switzerland, whose dried and powdered flowers, worked up with the curd, give the peculiar odour and flavour to Schabzieger (Chapziger) cheese; to the Faham tea-plant of the Mauritius (*Angræcum fragrans*); and to the common sweet woodruff (*Asperula odorata*). It acts powerfully upon the brain, and is probably the source of "hay-fever." Tonquin-beans are received in much smaller quantity into this country than into the United States. The exports from the ports of Ciudad Bolivar, in Venezuela, to New York, were 33,083¾ lb. in 1878, and 133,046¼ lb. in 1879.

Vanilla.—The seed-pods of the vanilla-plant possess an agreeable odour, which is prepared from them by extracting with rectified spirit, and used in the manufacture of compound scents. The pods possess much greater industrial importance as a flavouring ingredient, and their production and commerce will therefore be described at length under Spices.

PREPARED PERFUMES.

Extracts or Essences.—The simplest form of prepared perfume is the extract or essence, consisting of a solution of the principle in rectified alcohol. Some are mere artificial compounds, imitating the odour of the substance whose name they bear. The chief extracts are prepared as follows:—

Ambergris.—(*a*) Ambergris, 3 oz.; alcohol, 1 gal.

(*b*) Ambergris-extract, 1 pint; triple rose and musk extracts, each ½ pint; vanilla-extract, 2 oz.

Cedar.—Cedar-oil, 1 oz.; alcohol, 4 pint; triple rose extract, ¼ pint.

Civet.—Civet, 1 oz.; orris-root, 1 oz.; rubbed up in a mortar, and dissolved in 1 gal. alcohol.

Eglantine or Sweet-briar (imitation).—French rose-pomatum extract, 1 pint; cassie-extract, ¼ pint; orange-flower extract, ¼ pint; rose-extract, ¼ pint; neroli-oil, ½ dr.; lemon-grass-oil, ½ dr.

Heliotrope (imitation).—Vanilla-extract, ½ pint; French rose-pomatum extract, ¼ pint; orange-flower pomatum extract, 2 oz.; ambergris-extract, 1 oz.; almond-oil, 5 drops.

Honeysuckle (imitation).—Rose-pomatum extract, 1 pint; violet-extract, 1 pint; tuberose-extract, 1 pint; vanilla-extract, ¼ pint; tolu-extract, ¼ pint; neroli-oil, 10 drops; almond-oil, 5 drops.

Hovenia (imitation).—Dissolve ½ oz. lemon-oil, 1 dr. rose-oil, ½ dr. clove-oil, 10 drops neroli-oil, in 1 qt. alcohol, and add ½ pint rose-water.

Ilang-ilang.—Ilang-oil, 6 oz.; alcohol, 1 gal. (See also p. 1530).

Jonquil.—Jonquil-pomade, 8 lb.; alcohol, 1 gal.

Jonquil (imitation).—Jasmine-pomade extract, 1 pint; tuberose extract, 1 pint; orange-flower extract, ½ pint; vanilla-extract, 2 fl. oz.

Lavender.—Lavender-oil, 6 oz.; alcohol, 1 gal.

Lavender (Smyths').—Lavender-oil, 4 oz.; alcohol, 5 pints; rose-water, 1 pint; distil to 5 pints.

Lilac (imitation).—Tuberose-pomade extract, 1 pint; orange-flower pomade extract, ¼ pint; almond-oil, 3 drops; civet-extract, ½ oz.

Lily-of-the-Valley (imitation).—Vanilla-extract, 3 oz.; orange-flower extract, 2 oz.; jasmine-extract, 1 oz.; tuberose-extract, 1 pint; cassie-extract, ¼ pint; rose-extract, ¼ pint; almond-oil, 3 drops.

Lime-blossom (imitation).—Agar-attar (lignaloe-oil), 1 oz.; extracts of triple rose, jasmine, and orris, each ½ pint; alcohol, 2 pints.

Lignaloe (*Agar*).—Lignaloe-oil, 3 oz.; triple rose extract, 2 pints; jasmine-extract, 2 pints; tuberose-extract, 2 pints; orris-extract, 1 pint; vanilla-extract, 1 pint.

Magnolia (imitation).—Almond-oil, 10 drops; citron-zeste, 3 dr.; orange-flower pomade extract, 1 pint; tuberose-pomade extract, ½ pint; rose-pomade extract, 2 pints; violet-pomade extract, ½ pint.

Musk.—(*a*) Grain musk, 2 oz.; alcohol, 1 gal.

(*b*) Musk-extract, 1 pint; ambergris-extract, ½ pint; triple rose extract, ¼ pint.

Myrtle (imitation).—Rose-extract, 1 pint; vanilla-extract, ½ pint; orange-flower extract, ½ pint; tuberose-extract, ½ pint; jasmine-extract, 2 oz.

Narcissus (imitation).—Tuberose-extract, 3 pints; jonquil-extract, 2 pints; tolu-extract, ¼ pint; storax-extract, ¼ pint.

Orange-flower or Neroli.—Orange-flowers, 4 oz.; alcohol, 1 gal.

Orris.—Crushed orris-root, 7 lb.; alcohol, 1 gal.

Patchouli.—Patchouli-oil, 1¼ oz.; rose-oil, ¼ oz.; alcohol, 1 gal.

Pea [*Sweet-*] (imitation).—Tuberose, orange-flower, and rose-pomatum extracts, each ½ pint; vanilla-extract, 1 oz.

Pink [*Clove-*] (imitation).—Rose-extract, ½ pint; orange-flower and cassie extracts, each ¼ pint; vanilla-extract, 2 oz.; clove-oil, 10 drops.

Rose [*Chinese Yellow*].—Triple rose and tuberose extracts, each 2 pints; tonquin and verbena extracts, each ¼ pint.

Rose [*Moss*].—French rose-pomade extract, 1 qt.; triple rose and orange-flower extracts, each 1 pint; ambergris-extract, ½ pint; musk-extract, 4 oz.

Rose [*Tea*].—Rose-pomade, triple rose, and rose-leaf geranium extracts, each 1 pint; sandal-wood extract, ½ pint; orange-flower and orris extracts, each ¼ pint.

Rose [*Triple*].—Rose-oil, 3 oz.; alcohol, 1 gal.

Rose [*Twin*].—Rose-pomade, 8 lb.; French rose-oil, 1½ oz.; alcohol, 1 gal.

Rose [*White*].—Rose-pomade, triple rose, and violet extracts, each 1 qt.; jasmine-extract, 1 pint; patchouli-extract, ½ pint.

Sandal-wood.—Sandal-wood-oil, 3 oz.; rose-extract, 1 pint; alcohol, 7 pints.

Tolu-balsam.—Tolu-balsam, ½ lb.; alcohol, 1 gal.

Tonquin.—Tonquin-beans, 1 lb.; alcohol, 1 gal.

Tuberose.—Tuberose-pomade, 8 lb.; alcohol, 1 gal.

Vanilla.—Vanilla-pods, ½ lb.; alcohol, 1 gal.

Verbena (imitation).—(*a*) Lemon-peel-oil, 2 oz.; orange-peel-oil, ½ oz.; lemon-grass-oil, 3 dr.; alcohol, 1 pint.

(*b*) Orange-flower and tuberose extracts, each 7 oz.; lemon-peel-oil, 2 oz.; orange-peel-oil, 1 oz.; lemon-grass-oil, 2½ dr.; citron-zeste, 1 dr.; rose-extract, ½ pint; alcohol, 1 pint.

Violet (imitation).—Cassie-pomade extract, 1 pint; rose-pomade, tuberose-pomade, and orris extracts, each ½ pint; almond-oil, 3 drops.

Vitivert or Kuskus.—(*a*) Dried and chopped vitivert, 4 lb.; alcohol, 1 gal.

(*b*) Vitivert-oil, 2 oz.; alcohol, 1 gal.

Volkameria (imitation).—Violet and tuberose extracts, each 1 pint; rose extract, ½ pint; jasmine-extract, ¼ pint; musk-extract, 2 oz.

Wallflower (imitation).—Rose and orange-flower extracts, each 1 pint; vanilla, orris, and cassie extracts, each ½ pint; almond-oil, 5 drops.

Wintergreen.—Rose-extract, 1 pint; orange-flower and cassie extracts, each ½ pint; lavender, vanilla, and vitivert extracts, each ¼ pint; wintergreen-oil, 5 drops.

Incenses and Pastilles.—These names are applied to compositions which perfume by fumigation, i. e. emit their odour by undergoing slow and incomplete combustion. The following are the chief recipes for their preparation:—

Bruges Ribbon.—Mix ½ pint orris-extract, ¼ lb. gum benzoin, and ¾ oz. gum myrrh, in one bottle; and ½ pint alcohol, ½ oz. pod musk, and 1 dr. rose-oil, in another. Let stand 1 month. Steep undressed cotton tape in a solution of 1 oz. nitrate of potash in 1 pint hot rose-water; dry it; filter and mix the contents of the two bottles, steep the ribbon, and dry it.

Incense-powder.—1 lb. powdered sandal-wood, ½ lb. each powdered cascarilla-bark and gum-benzoin, 2 oz. each vitivert and nitrate of potash, and ¼ dr. grain musk, well sifted together.

Perfumers' Pastilles.—Wood-charcoal, 1 lb.; gum benzoin, ¾ lb.; tolu balsam, vanilla-pods, and cloves, each ¼ lb.; sandal-wood- and neroli-oils, each 2 dr.; nitrate of potash, 1½ oz. in gum tragacanth as before.

Piesse's Pastilles.—Willow-charcoal, ½ lb.; benzoic acid, 6 oz.; thyme-, caraway-, rose-, lavender-, clove- and sandal-wood-oils, each ½ dr.; grain musk, 1 dr.; civet, ¼ dr.; before mixing, ¾ oz. nitrate of potash is dissolved in ½ pint rose-water; the charcoal is thoroughly wetted with this solution, then dried; the mixed oils are poured over it, and the benzoic acid is stirred in; the whole is well mixed, and then beaten up with a gum mucilage.

Seraglio Pastilles.—Gum benzoin, 60 gr.; poplar-charcoal, 190 gr.; sandal-wood, 15 gr.; tolu balsam, 8 gr.; laudanum, 4 gr.; nitrate of potash, 8 gr.; mucilage of gum tragacanth, 9½ gr.

Yellow or Indian Pastilles.—Powder and mix by sifting 1 lb. sandal-wood, 1½ lb. gum benzoin, and ¼ lb. tolu balsam; add 3 dr. each of sandal-wood-, cassie-, and clove-oils; then 1½ oz. nitrate of potash, dissolved in enough mucilage of gum tragacanth to make a stiff paste of the whole.

Nosegays or Bouquets.—By far the greatest part of the scent consumed is in this form, being, as the names indicate, mixtures of a number of odoriferous extracts. The principal recipes are as follows:—

Alhambra.—Tuberose-extract, 1 pint; geranium-extract, ½ pint; acacia-, civet-, and orange-flower extracts, each ¼ pint.

d'Amour.—Pomade-extracts of rose, jasmine, violet, and cassie, each 1 pint; musk- and ambergris-extracts, each ½ pint.

d'Andorre.—Pomade-extracts of rose, jasmine, violet, and tuberose, each 1 pint; orris-extract, 1 pint; geranium-oil, ¼ oz.

Bosphorus.—Acacia-extract, 1 pint; triple rose, jasmine, tuberose, and orange-flower extracts, each ½ pint; civet-extract, ¼ pint; almond-oil, 10 drops.

Buckingham Palace.—Pomade-extracts of rose, jasmine, cassie, and orange-flower, each 1 pint; ambergris- and orris-extracts, each ½ pint; rose-oil, 1 dr.; neroli- and lavender-oils, each ½ dr.

Caroline or des Délices.—Pomade-extracts of rose, violet, and tuberose, each 1 pint; ambergris- and orris-extracts, each ½ pint; citron-zeste, ½ oz.; bergamot-oil, ¼ oz.

Court.—Rose-, violet-, triple rose-, and jasmine-extracts, each 1 pint; ambergris- and musk-extracts, each 1 oz.; citron-zeste and bergamot-oil, each ½ oz.; neroli-oil, 1 dr.

Eugénie.—Geranium-, triple rose-, and sandal-wood-extracts, each ½ pint; musk-, vanilla-, neroli-, and tonquin-bean extracts, each ¼ pint.

Ess.—Triple rose-extract, 1 pint; orris-extract, 8 oz.; ambergris-extract, 2 oz.; bergamot-oil, 1 oz.; lemon-oil. ¼ oz.

Eszterhazy.—Pomade-extract of orange-flower, and extracts of triple rose, vitivert, vanilla, orris, tonquin-beans, and neroli, each 1 pint; ambergris-extract, ½ pint; sandal-wood-oil, 1 oz.; clove-oil, ½ dr.

de Flora.—Pomade-extracts of rose, tuberose, and violet, each 1 pint; benzoin-extract, 1½ oz.; bergamot-oil, 2 oz.; citron- and orange-zestes, each ½ oz.

Flowers of Erin.—White rose extract, 1 pint; vanilla-extract, 1 oz.

Guards'.—Rose-extract, 2 pints; vanilla-, orris-, and orange-flower extracts, each ½ pint; musk-extract, ¼ pint; clove-oil, ½ dr.

Holy Basil.—Vanilla-, geranium-, and tonquin-bean-extracts, each 2 pints; cassie-, jasmine-, tuberose-, tolu-, orange-flower-, and Montserrat lime-essences, each 1 pint.

Ilang-ilang.—Rose-pomade-, triple rose-, cassie-, jasmine-, and tuberose-extracts, each 1 pint; orris-extract, 2 pints; ilang-oil, 1 oz.; pimento-oil, ¼ oz.; alcohol, 1 pint.

International.—Violet-extract, 1 pint; triple rose-, jasmine-, and tuberose-extracts, each ½ pint; lavender-, vanilla-, sandal-wood-, musk-, and patchouli-extracts, each ¼ pint; lemon-oil, ¼ oz.; citronella-oil, 1 dr.

Isle of Wight.—Sandal-wood-extract, 1 pint; rose- and orris-extracts, each ½ pint; vitivert-extract, ¼ pint.

Italian.—Rose-pomade extract, 2 pints; extract of triple rose, and pomade-extracts of jasmine and violet, each 1 pint; cassie-extract, ½ pint; musk- and ambergris-extracts, each 2 oz.

Jockey Club (English).—Orris-extract, 2 pints; triple rose extract and rose pomade extract, each 1 pint; extract of ambergris, and pomade-extracts of cassie and tuberose, each ½ pint; bergamot-oil, ½ oz.

Jockey Club (French).—Rose-pomade extract and tuberose-extract, each 1 pint; jasmine-extract, ¾ pint; cassie-extract, ½ pint; civet-extract, 3 oz.

Kew Garden.—Orange-flower-extract, 1 pint; pomade-extracts of cassie, tuberose, and jasmine, and extract of geranium, each ½ pint; musk- and ambergris-extracts, each 3 oz.

Leap-year.—Jasmine- and tuberose-extracts, each 1 pint; extracts of triple rose, sandal-wood, patchouli, and vitivert, each ½ pint; verbena-extract, 1 gill.

du Maréchal.—Triple rose and orange-flower extracts, each 1 pint; vitivert-, vanilla-, orris-, tonquin-bean, and neroli-extracts, each ½ pint; ambergris- and musk-extracts, each ¼ pint; clove- and sandal-wood-oils, each ½ dr.

May Flowers.—Vanilla-extract, 1 pint; rose-, jasmine-, cassie-, and orange-flower-extracts, each ½ pint; almond-oil, ¼ dr.

de Montpellier.—Rose-pomade extract, and tuberose- and triple rose-extracts, each 1 pint; ambergris- and musk-extracts, each ¼ pint; bergamot-oil, ½ oz.; clove-oil, 1½ dr.

New-mown Hay.—Tonquin-bean-extract, 2 pints; geranium-, orange-flower-, jasmine-, rose-, and triple rose-extracts, each 1 pint.

Opoponax.—Infuse 1 oz. pod musk, 8 oz. vanilla, 4 oz. tonquin-beans in 10 pints alcohol for 1 month; then add 8 pints millefleur pomade-extract, 4 pints orris-extract, 2 oz. each citron-zeste and bergamot-oil, 1½ oz. rose-oil, and ½ oz. opoponax-oil.

de la Reine d'Angleterre.—Pomade-extracts of rose and violet, each 1 pint; tuberose-extract, ½ pint; orange-flower-extract, ¼ pint; bergamot-oil, ¼ oz.

du Roi.—Pomade-extracts of rose, violet, and jasmine, each 1 pint; vanilla- and vitivert-extracts, each ¼ pint; ambergris- and musk-extracts, each 1 oz.; clove-oil, 1 oz.; bergamot-oil, 1 dr.

Rondeletia.—Lavender-oil, 2 oz.; bergamot- and clove-oils, each 1 oz.; rose-oil, 3 dr.; ambergris-, musk-, and vanilla-extracts, each ¼ pint; alcohol, 1 gal.

Royal Hunt.—Triple rose extract, 1 pint; acacia-, neroli-, musk-, orris-, and orange-flower-extracts, each ¼ pint; tonquin-bean extract, ½ pint; citron-zeste, 2 dr.

Piesse's Posy.—Rose-pomade-extract, 1 pint; extract of triple rose, and pomade-extracts of violet and jasmine, each ½ pint; verbena- and cassie-extracts, each 2½ oz.; ambergris- and musk-extracts, each 1 oz.; bergamot- and lemon-oils, each ¼ oz.

Spring Flowers.—Pomade-extracts of rose and violet, each 1 pint; cassie- and triple rose-extracts each 2½ oz.; ambergris-extract, 1 oz.; bergamot-oil, 2 dr.

Suave.—Pomade-extracts of rose, cassie, jasmine, and tuberose, each 1 pint; vanilla-extract, 5 oz.; ambergris- and musk-extracts, each 2 oz.; bergamot-oil, ¼ oz.; clove-oil, 1 dr.

Tulip.—Pomade-extracts of jasmine, violet, and tuberose, each 1 pint; rose-extract, ½ pint; orris-extract, 3 oz.; almond-oil, 2 drops.

Volunteers'.—Orris-extract, 1 pint; cassie- and jasmine-extracts, each ¼ pint; ambergris- and musk-extracts, each 2½ oz.; rose-, neroli-, bergamot-, and lavender-oils, each ¼ oz.; clove-oil, 8 drops; alcohol, 1 pint.

West-End.—Triple rose extract, 3 pints; violet-, cassie-, jasmine-, and tuberose-extracts, each 1 pint; ambergris- and musk-extracts, each ½ pint; bergamot-oil, 1 oz.

Wood-Violet.—Violet-extract, 1 pint; cassie-, orris-, and rose-pomade-extracts, each 3 oz.; almond-oil, 3 drops.

Yacht Club.—Neroli- and sandal-wood-extracts, each 1 pint; triple rose- and jasmine-extracts, each ½ pint; vanilla-extract, ¼ pint; benzoin-flowers, ¼ oz.

Satchets.—Perfumes intended to be placed in satchets, or ornamental receptacles of paper, silk, &c., must be such as retain their fragrance in a dry state. These are ground very fine, and compounded according to the subjoined formulæ:—

Cassie.—Cassie-heads, 1 lb.; orris-root, 1 lb.

Cyprus.—Rose-wood, cedar-wood, and sandal-wood, each 1 lb.; rose-wood-oil, 3 dr.

Frangipanni.—Orris-root, 3 lb.; vitivert and sandal-wood, each ¼ lb.; rose-, neroli-, and sandal-wood-oils, each 1 dr.; musk pods, 1 oz.; civet, ¼ oz.

Heliotrope.—Orris-root, 2 lb.; rose-leaves, 1 lb.; tonquin-beans, ½ lb.; vanilla-beans, ¼ lb.; grain musk, ¼ oz.; almond-oil, 5 drops.

Lavender.—Lavender-flowers, 1 lb.; gum benzoin, ¼ lb.; lavender-oil, ¼ oz.

Maréchale.—Sandal-wood and orris-root, each ½ lb.; rose-leaves, cloves, and cassia-bark, each ¼ lb.; grain musk, ½ dr.

Millefleur.—Lavender-flowers, orris-root, rose-leaves, and gum benzoin, each 1 lb.; tonquin-beans, vanilla-beans, cloves, and sandal-wood, each ¼ lb.; cinnamon and allspice, each 2 oz.; musk and civet, each 2 dr.

Mousseline.—Vitivert, 1 lb.; orris-root, sandal-wood, and black-currant leaves, each ½ lb.; gum benzoin, ¼ lb.; rose-oil, ½ dr.; thyme-oil, 5 drops.

Patchouli.—Patchouli-herb, 1 lb.; patchouli-oil, ¼ dr.

Peau d'Espagne.—Rose-, neroli-, and sandal-wood-oils, each ½ oz.; lavender-, verbena-, and bergamot-oils, each ¼ oz.; clove- and cinnamon-oils, each 2 dr.; then add a solution of 4 oz. gum benzoin in ½ pint alcohol; steep pieces of wash-leather in the mixture for a day or two; squeeze out, and dry. Rub up a paste of 1 dr. each of civet and grain musk with enough gum mucilage to give a spreading consistence; spread the paste on one side of the skin pieces; place two pieces together with the pasted sides facing, and sew up in silk bags.

Portugal.—Orange-peel, 1 lb.; lemon-peel and orris-root, each ½ lb.; orange-peel oil, 1 oz.; neroli- and lemon-grass-oils, each ¼ dr.

Pot-pourri.—Lavender, rose-leaves, and salt, each 1 lb.; orris-root, ½ lb.; cloves, cinnamon, and allspice, each 2 oz.

Rose.—Rose-heels or leaves, 1 lb.; sandal-wood ½ lb.; rose-oil, ¼ oz.

Verbena.—Lemon-peel, 1 lb.; lemon-thyme, ¼ lb.; bergamot-oil, 1 oz.; lemon-peel-oil, ½ oz.; lemon-grass-oil, 1 dr.

Violet.—Black-currant-leaves, cassie-heads, and rose-heels or leaves, each 1 lb.; orris-root, 2 lb.; gum benzoin, ½ lb.; grain musk, 1 dr.; almond-oil, ¼ dr.

Vinegars [Aromatic].—See p. 335.

Waters and Eaux.—The term "water," or its French equivalent *eau*, is applied to some few compound scents, without any very obvious reason. The principal of these are constituted as follows:—

des Carmes.—Fresh leaves of *Melissa officinalis*, 2 lb.; fresh lemon-peel, ¼ lb.; nutmeg, coriander seeds, cloves, cinnamon, and angelica root, all broken fine, each 2 oz.; the whole is placed in a still with ½ gal. orange-flower-water and 1 gal. alcohol, and distilled slowly till 1 gal. has condensed.

de Chypre.—Musk-extract, 1 pint; extracts of ambergris, orris, vanilla, and tonquin-bean, each ½ pint; triple rose extract, 2 pints.

de Cologne.—(*a*) Grape-alcohol, 6 gal.; orange and citron zestes, each 5 oz.; neroli-oil, 3 oz.; rosemary and bergamot oils, each 2 oz.; bigarade oil, 1 oz.

(*b*) Grain-alcohol, 6 gal; lemon, bergamot, and orange-peel oils, each 4 oz.; rosemary and petit grain oils, each 2 oz.; neroli-oil, ½ oz.

Elder-flower.—Distil 12 lb. of the flowers with water until that passing into the receiver has no perfume—usually 15–18 lb.; to the distillate, add 12 lb. alcohol, and distil 5 lb. from it. Of this, mix 2 oz. with 10 oz. distilled water.

Hungary.—Grape-alcohol, 1 gal.; rose- and orange-flower extracts, each 1 pint; Hungarian rosemary-oil, 2 oz.; lemon-peel and *Melissa* oils, each 1 oz.; mint-oil, ½ dr.

Lavender.—English lavender-oil, 4 oz.; alcohol, 3 qt.; rose-water, 1 pint.

Lisbon.—Alcohol, 1 gal.; orange-peel-oil, 4 oz.; citron zeste, 2 oz.; rose-oil, ¼ oz.

de Luce.—Benzoin or Peru balsam extract, 1 oz.; lavender-oil, 10 drops; liquor ammonia, 2 oz.; oil of amber, 5 drops.

de Millefleurs.—Triple rose extract, 1 pint; pomade-extracts of rose, jasmine, tuberose, orange-flower, cassie, and violet, each ½ pint; cedar-extract, ¼ pint; musk, ambergris, and vanilla extracts, each 2 oz.; bergamot-oil, 1 oz.; clove-, almond-, and neroli-oils, each 10 drops.

de Mousseline.—Maréchale bouquet, 1 pint; pomade-extracts of jasmine, cassie, tuberose, and rose, each ½ pint; sandal-wood-oil, 2 dr.

de Portugal.—Alcohol, 1 gal.; orange-peel-oil, 8 oz.; citron zeste, 2 oz.; bergamot-oil, 1 oz.; rose-oil, ¼ oz.

Rose.—The preparation of rose-water has been described at length under rose-oil (see p. 1427).

Imports and Values.—Our imports of unenumerated perfumery, independent of essential oils (see p. 1483), in 1879, were:—From Holland, 687,391 lb., value 25,057*l.*; France, 320,985 lb., 27,676*l.*; China, 4988 lb., 49,561*l.*; other countries, 167,960 lb., 23,772*l.*; total, 1,181,324 lb., 126,066*l.* The approximate London market values of the principal commercial raw perfumes are:—Ambergris, 45–85*s.* an oz.; Aniseed, 26–40*s.* an oz.; Star anise, 80–105*s.* an oz.; Musk, pod, 13–65*s.* an oz., grain, 30–70*s.* an oz.; Civet, 11*s.* an oz.; Castor, 12–26*s.* a lb.; Orris-root, 20–45*s.* a cwt.; Tonquin-beans, 4*s.* 6*d.*–7*s.* a lb.; Sandal-wood, 10–60*s.* a ton.

Bibliography.—C. Morfit, 'Perfumery: its Manufacture and Use' (Philadelphia: 1853); H. Dussauce, 'Treatise on Perfumery' (Philadelphia: 1864); E. Rimmel, 'Book of Perfumes' (London: 1865); R. J. Owen, 'Practice of Perfumery' (London: 1870); G. W. S. Piesse, 'Art of Perfumery' (4th ed. London: 1879); J. Fuchs, 'Castoreum' (Pharm. Jour., Vol. xi., No. 565, p. 875, London: 1881); G. W. Askinson, 'Parfumerie-Fabrikation' (Leipzig).

PHOTOGRAPHY (Fr., *Photographie*; Ger., *Photographie*, *Lichtbildkunst*).

The history of photography is the history of half a century of progress almost without parallel in the annals of science. Many of the photographic processes which followed the discoveries of Daguerre and Talbot have either become obsolete, or have been absorbed in processes of more permanent value.

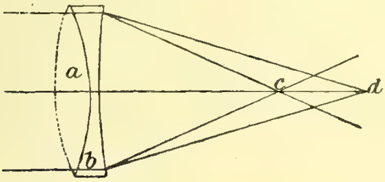
In the present article, it is proposed to deal with the modern phases of photography, leaving out of consideration the early history and progress of the art. It will be convenient to treat the subject under three heads; viz. Photographic Instruments and Appliances, Modern Photographic Processes, and Modern applications of Photography.

Photographic Instruments.—Without the camera and its lens, the majority of photographic processes would be practically useless. The photographic camera obscura—dark chamber—with its image-forming lens, may be likened to the human eye, whose retina finds its mimicry in the sensitive photographic plate upon which the image falls, and is impressed. The eye is a perfect optical instrument, whose lens and iris, or diaphragm, so adjust themselves in focus, and to the varying conditions of light, as to transmit faultless images of outer objects to the retina. The camera-lens, modelled on the same plan, transmits what are termed perfectly achromatized images to the prepared photographic plate. In lieu of an iris expanded and contracted by muscles, the camera-lens carries metallic diaphragms, and has a mechanical arrangement, by which it may be focussed for near or distant objects.

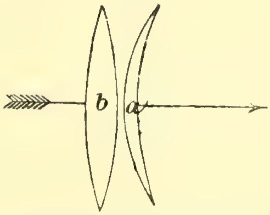
Objectives.—The lens is of primary importance in photography; it becomes necessary, therefore, to point out the conditions which fit the lens for its photographic functions. It will simplify matters to employ the term "objective" in place of lens, since all useful photographic lenses are combinations of two or more lenses of different foci. The first condition is to have the objective perfectly achromatized, i. e. the visual and chemical foci coincident, in other words, the chemical rays which impress the image upon the plate, and the rays which form the visible image upon the screen, should have their focus at the same point. The objective should be also free from spherical aberration; that is to say, the image transmitted by the combined lenses should neither be curved nor distorted.

Should the double-convex lens *a* (Fig. 1078), and the double-concave lens *b*, be made of crown-glass, chromatic aberration will be represented by the points of focus *c d*. The parallel rays of white light incident upon the lens *a* will be split up into seven coloured rays, each having a different degree of refrangibility, and a different focus. The red rays, having a small index of refraction, 1·5258, will have their focus at *c*, while the extreme violet rays, having a greater index of refraction, 1·5466, will have their focus at *d*, and the distance between *c* and *d* will represent the chromatic aberration of the combined lenses. Taking advantage of the difference in the dispersive power of flint- and crown-glass, if the lens *a* is made of crown-glass, whose index of refraction is 1·519, and dispersive power 0·036, and the lens *b* of flint-glass, whose index of refraction is 1·589, and dispersive power 0·0393, and if the focal length of the crown-glass is 4½ in., and that of the flint-glass 7⅔ in., they will form a lens of 10 in. focus, and will refract white light to a single focus free from colour. By this means, is obtained an achromatized combination suitable for photographic purposes. Spherical aberration may be completely corrected by the forms of the combined lenses. Thus, by combining a miniscus lens (Fig. 1079) *a* with a double-convex lens *b*, the aberration produced by the lenses when used singly will disappear.

1078.



1079.



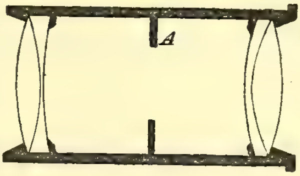
The result of having the objectives corrected is that they throw a sharply defined image upon the screen of the camera, and produce a sharply defined image upon the photographic plate. Suitable objectives must therefore be what are termed "achromatic combinations," and are made by uniting two or more lenses of flint- and crown-glass of different refracting powers.

Objectives supplied by well-known makers fulfil, as a rule, all the conditions necessary for successful photography. They distribute illumination equally over the plate, and are free from flare and distortion.

The objective commonly used in portraiture is made up of four lenses, two of flint-, and two of crown-glass. Seeing that the majority of portraits are taken indoors, with a comparatively feeble light, the portrait-objective must be used with a wide aperture, so as to admit the maximum of light. Even with the best portrait-objective, when no diaphragm is employed, the image is apt to lack clearness and definition on its outer edge.

Diaphragms.—In the portrait-objective, as in most other combinations, the diaphragm is placed midway between the front and back lenses, as in Fig. 1080. The object of the diaphragm at A is to impart distinctness to every part of the picture. By employing a very small aperture in the diaphragm, a portrait or landscape may be rendered so distinct all over its surface as to closely resemble a map. Judgment is therefore required in the use of diaphragms, so as to secure the necessary degree of distinctness without losing the effect of relief and distance. The use of small diaphragms is restricted in another way; the smaller the aperture employed, the longer will be the time required to produce a picture.

1080.

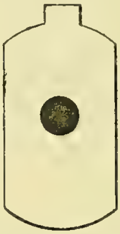


Waterhouse diaphragms are those most commonly used. They are made of thin plates of blackened brass, pierced with an aperture (Fig. 1081), and calculated to slip into a slit in the inner lens-tube (Fig. 1082).

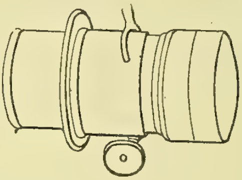
When great rapidity is required, as in photographing children, the diaphragm is dispensed with, and the objective is worked with full aperture. In copying a map or plan full of minute detail, the smallest diaphragm yields the most perfect definition.

Modern objectives for landscape and architectural photography are so perfectly corrected as to produce faultless images. With what are known as "symmetrical" and "rectilinear" lenses, the straight lines of a building are reproduced as straight lines. With the old miniscus, or plano-convex landscape lenses, there was always a degree of curvature and distortion, which greatly marred the photographs taken by them.

1081.



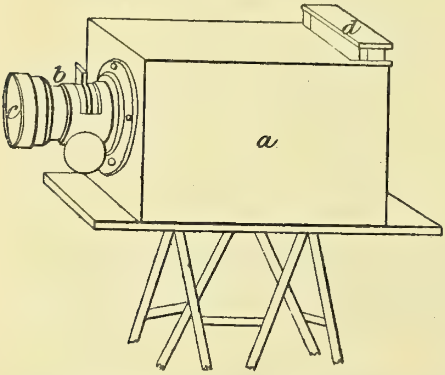
1082.



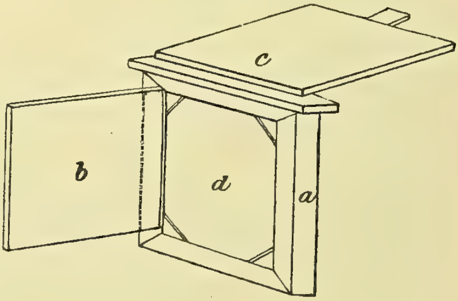
Another improvement effected in the construction of landscape-objectives is the larger field which some of them are made to cover, embracing an angle of over 90°. These render it possible to photograph, without distortion, objects near at hand and of great elevation. Special objectives are also made to cover a large field, and to be used with an aperture wide enough to fit them for taking groups, and instantaneous street views. The London opticians, Ross and Dallmeyer, have indeed brought photographic optics to a degree of perfection which leaves little or nothing to be desired.

Cameras.—The camera obscura or dark chamber of photography, to which the objective is attached, is presented in its rudimentary form in Fig. 1083. The mahogany box *a* is made perfectly lightproof; the objective *b* has a movable inner brass tube with rack and pinion for focussing; *c* is the front cap for timing exposure; and *d* is a ground-glass screen used in focussing, upon which the image falls. By throwing a dark cloth over the head, and the end of camera, the operator is enabled to see and adjust the inverted image on the ground glass. When the image is centred and focussed, the screen is withdrawn, and replaced by a sensitive plate in a dark closed carrier (Fig. 1084). The dark slide is composed of a strong outer frame *a*, while *d* represents the open space, with corners upon which the prepared plate rests. Exposure is effected by the front draw-up shutter *c*; and the back shutter *b* opens to receive the plate.

1083.



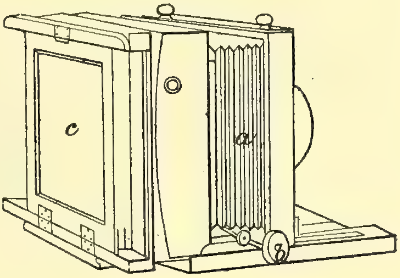
1084.



The plate, prepared in a chemically dark room, is then consigned to the slide, which is closed, and carried to the camera, where it is exposed; it is finally taken back to the dark room, and developed.

There are an infinite variety of cameras, each designed to serve some special end, and all of them framed on the principle of the instrument described. But the camera in its most advanced state is a complex instrument, in general form represented by Fig. 1085. The rigid rudimentary body is replaced by a bellows *a*, fixed to the front and back of the instrument. This bellows is expanded and contracted by rack and pinion at *b*, to suit objectives of different foci. The back swings vertically and horizontally, and may be fixed at any angle by pinching-screws. The swing back is useful in obtaining more uniform focus, where a near and distant object have to be photographed together on one plate. Another advantage in this instrument is its perfect portability. The baseboard is so framed as to admit of the camera being folded up into very small compass. The slides or plate-carriers attached to this instrument are both single and double. The single slide is used for the "wet collodion" process, and the double, which carries two plates, for the "dry" process.

1085.

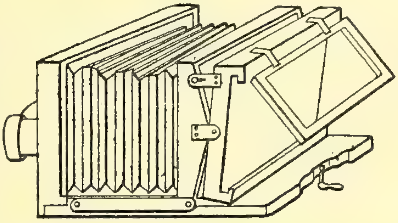


Stereoscopic camera.—The stereoscopic camera, in its most complete form, carries two objectives about 4 in. apart. By this means, two pictures of the same object are taken at once. These, when reversed, and combined by the stereoscope, produce a mimicry of objects in relief. (Figs. 1086–7.)

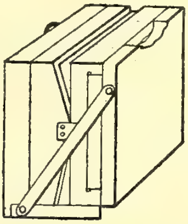
Enlarging camera.—When the object to be photographed is focussed on the screen, and the distance of the objective from the focussing screen is greater than the distance of the objective from the object, an enlarged image of the object is obtained. The enlarging camera is thus capable of considerable expansion, and herein lies the main difference of the enlarging camera from the instrument required for small photographs.

The solar camera for direct enlargement carries a mirror and large condensing lens. The mirror is designed to transmit the solar rays through the condenser, which in turn illuminates the negative to be enlarged. The method by which the enlarged image is obtained is a counterpart of what takes place in the magic lantern, with this difference, that the source of light in the camera is the sun. The limelight lantern has, indeed, to some extent taken the place of the solar camera in modern practice.

1086.



1087.



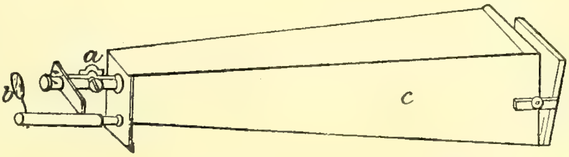
Micro-photographic camera.—The principle embodied in the micro-photographic camera is the same as that involved in the foregoing apparatus. It is shown in Fig. 1088: *a*, microscope; *b*, reflecting mirror; *c*, camera.

Photo-micrographic camera.—The photo-micrographic camera is a diminishing apparatus, and may be set down as the micro-photographic camera reversed. Reduced photographs of official despatches, obtained by this instrument, were largely used during the Franco-Prussian war for transmission by pigeon-post.

Kinnear's portable landscape camera is shown in Figs. 1089 and 1090.

Instantaneous shutters.—With the advent of what are termed "gelatine-emulsion" plates, came the necessity of rapid exposures, exposures too rapid for the handwork of uncapping and capping the lens. This necessity has been met by shutters made to fit the front of the objective. Some of these are pierced with an aperture, which drops over the front of the lens at the moment of exposure. Others open and close instantaneously, by means of electricity or pneumatic pressure. But Dr. Vogel's shutter is perhaps the simplest of all. It consists of a black velvet sleeve A (Fig. 1091), fixed to the front of the camera B. At the end of the sleeve, is a light wooden board C, pierced with an oblong hole D. When the plate is ready for exposure, the board, which has been laid back on the top of the camera, is lifted, and dropped vertically in front of the lens. The passage of the aperture D across the field effects a momentary exposure of the plate.

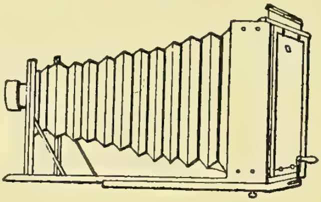
1088.



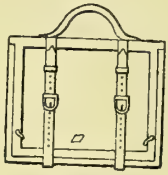
In addition to the instruments described, there are many others used in photography, too complex to admit of anything beyond passing notice in the present article. The simplest of these are actinometers, for determining the actinic power of light. There are instruments for registering barometric and thermometric changes, the vibrations of the magnetic needle, and the phenomena of the interference of the rays of the spectrum. De La Rue, Rutherford, Grubb, and Huggans, are names intimately associated with astronomical photography. Specially-constructed telescopes, made to follow the movements of our globe and of the planets, have been constructed. By means of these, the moon has been photographed, and, more wonderful still, the spectra of planets and of stars.

The Dark Room.—It is most essential in all photographic processes to employ what is termed a "dark room" in all operations connected with preparing and developing the sensitive plate. This dark room is not without light, but its light is of a quality such as in no way affects the plate. It should be lighted from a small window covered with one or two thicknesses of orange paper, and furnished with a blind of Turkey red. When this blind is drawn down, sufficient light should pass through to enable the operator to see what he is about, and yet the light is so inactinic as to be harmless to the most sensitive plate during preparation and development. Beneath the window, there should be a water-tap and leaden sink for washing purposes. Rows of shelves right and left should also be fixed within reach. These are handy for storing bottles. An ample deal bench, flush with the top of the sink, and made to slide over it, facilitates operations.

1089.



1090.

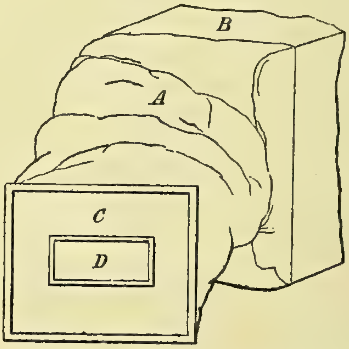


The Studio.—The "studio" pertains to professional photography, and is worthy of special notice. It is simply a well-lighted apartment in close proximity to the dark room. It used to be constructed almost entirely of glass, but that has become unnecessary, since a photograph can be taken in a fraction of a second. It is indeed advisable to dispense with much of the light of the old studio, so as to secure more artistic effect in portraiture. The apartment should recall a well-appointed drawing-room rather than a photographic studio. In the construction of a studio, it should be borne in mind that a steady north light is the best to work by, and that, by an arrangement of blinds, the light may be so manipulated as to suit any subject.

White reflecting screens are also of great use in lighting the dark portions of the object to be photographed.

Studio accessories may be left entirely to the taste and skill of the photographer. The intelligent selection and use of these are of the highest importance in the production of artistic photographs.

1091.



Camera Stands.—The studio-stand should be a solid piece of furniture, and yet easily moved about. It is so made that, by simple mechanism, the camera may be raised, depressed, or angled, at convenience. Portable tripod stands are supplied for outdoor work. These are so light as to be used as an alpenstock, and, when expanded, so rigid as to render the camera perfectly immobile.

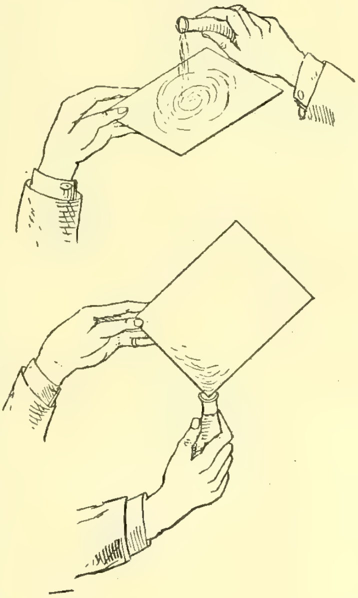
The foregoing summary of the instruments and appliances used in photography is far from exhaustive. It is simply suggestive of the progress made in this direction, and intended also to render the processes of photography more intelligible to the reader.

Processes.—*Collodion Process.*—"Negative" and "positive" are terms employed to denote respectively the photograph taken in the camera and the print obtained from the plate so taken. The negative usually consists of a sheet of glass, which affords support for the chemicals required to produce a photograph. Collodion charged with haloid salts is one of the vehicles used to coat the plate, and is made by dissolving gun-cotton (pyroxyline) in ether and alcohol. Pyroxyline may be prepared in the following manner:—10 dr. cotton, 52 oz. sulphuric acid, 18 oz. nitric acid, 8 oz. water; the cotton should be of fine quality, and boiled for $\frac{1}{2}$ hour in 2 oz. caustic soda and 1 gal. water. It must then be freed from the alkali by washing in water, and dried. The acids and water should now be mingled in a porcelain jar, and left to fall to $65\frac{1}{2}°$ (150° F.), when the cotton may be plunged in, and left for 10 minutes. When taken out, it should be washed thoroughly with water, and dried, care being taken not to heat and ignite the compound, as it is highly explosive.

To make the collodion, take 10 oz. alcohol, 5 oz. sulphuric ether, and 100 gr. cotton. The above solution may be fitted for use by adding 5 oz. alcohol, 60 gr. ammonium iodide, 30 gr. cadmium iodide, 20 gr. cadmium bromide. Shake well, and allow to settle for 12 hours.

The collodion may now be used for coating the glass plate. This operation is best conducted in daylight. The fluid is flowed over the glass, and drained off at one corner (Fig. 1092). In about 2 minutes, it will have set, and may be carried to the dark room, and there plunged into an upright glass bath containing 600 gr. silver nitrate, and 20 oz. distilled water. This first plate should be allowed to remain in the bath for 12 hours, after which, it should be withdrawn, when the nitrate bath will be ready for use.

1092.



Prepare another plate, and consign it to the bath, where it should remain until the greasy appearance has left the surface of the collodion film. The plate may now be placed in the dark slide of the camera, and carried to the studio, where exposure in the camera is effected.

Development.—After exposure in the camera, the plate is carried to the dark room, and there taken out of the slide. No visible change will be observed on the plate. The image is impressed, but it is latent, and may be evoked by pouring over the film a solution containing 1 oz. iron protosulphate, 1 dr. copper sulphate, 1 oz. baryta nitrate, $\frac{1}{2}$ oz. glacial acetic acid, 20 oz. water. Filter out the white precipitate, and it is ready for use.

Another formula is—$\frac{1}{4}$ oz. iron protosulphate, $\frac{1}{4}$ oz. glacial acetic acid, $\frac{1}{2}$ oz. alcohol, 8 oz. water.

Either of the above solutions may be successfully employed, but the proportions can be varied, and different reagents used in developing the latent image. After washing off all trace of the developing solution, the negative may be intensified by flowing over the plate 3 gr. pyrogallic acid, 3 gr. citric acid, 1 oz. water. To this is added, just before using, one or two drops of a mixture of 30 gr. silver nitrate and 1 oz. distilled water.

The object of intensifying is to confer the degree of opacity upon the lights necessary to yield a brilliant positive print.

If the subject be a portrait, the extreme high-lights should appear quite opaque when the plate is held up and viewed by transmitted light. When fully intensified, the plate may be washed under the tap, and fixed either by lowering into a bath containing a nearly saturated solution of sodium hyposulphite in water, or pouring over the film a solution of 100 gr. potassium cyanide to 10 oz. water.

In any case, after the negative has been cleared of the unaltered opalescent bromo-iodide of silver, it must be thoroughly washed under the tap, and reared up to dry. When dry, the negative should be slightly heated, and the following varnish (which has been filtered) applied:—1 oz. sandarac, 4 dr. seed-lac, 1 dr. castor-oil, 9 oz. alcohol. The varnish must be poured over the collodion film, and drained off at one corner of the plate, which must again be heated to drive off the alcohol, and harden the surface.

In this wet collodion process, there are distinctly marked stages of progress. The bromo-iodized collodion is in itself insensitive to light, and may be exposed to sunshine without detriment. So indeed is the silver nitrate solution. But a great transition takes place when the collodionized plate is plunged into the silver bath. The iodide and bromide in the collodion form a union with the silver salt, and produce a highly sensitive film of bromo-iodide of silver. On the successful formation of this powerful compound, hinges the entire result of the process. Should the silver bath prove too acid, the negative will be hard black and white. On the other hand, if the bath is alkaline, the negative will fog over, and lack contrast. Should white light fall upon the plate when it is sensitized, and before it is developed, the negative will fog hopelessly. If the glass plate has not been thoroughly cleaned before coating with collodion, stains will show after development. Dust flying about in the dark room and settling on the plate will cause pinholes in the negative. These may also be caused by sediments in the collodion, or in the silver bath.

Dry Collodion Processes.—The dry collodion processes are falling into disuse before their formidable rival dry gelatine emulsion. Even were they not destined to become processes of the past, they are too numerous to catalogue.

Plates prepared in the way described under the head of Collodion Process may be dried and preserved for an indefinite length of time. After leaving the silver bath, it is only needful to wash them thoroughly under the tap, and flow over them 20 gr. tannin in 1 oz. water, after which, they may be dried in a dark place, and preserved for use.

Preservatives other than tannin may be used without number, but one will serve as a type of all the others. Washing, preserving, and drying greatly reduce the sensitiveness of wet collodion plates. But this defect is to some slight extent counteracted by employing an alkaline developer:

—(*a*) 3 gr. pyrogallic acid, 1 oz. water; (*b*) 30 gr. potassium bromide, 1 oz. water; (*c*) 30 gr. ammonium carbonate, 1 oz. water.

To ½ oz. of pyrogallic solution, add 2 minims of *b*, and three of *c*. Should the image come out slowly, and be wanting in detail, add 2–3 min. of ammonia carbonate. The alkali will also add to the vigour of the negative when the image has been fully developed.

Collodion Emulsion Process.—Collodion emulsion is a mixture of iodized or bromo-iodized collodion and silver nitrate.

Washed Collodion Emulsion.—Collodion made as already described with the iodizer added should be carried to the dark room, and mixed with 1 oz. collodion, 2 min. acetic acid, 1 dr. glycerine, 4 dr. alcohol. Shake up, and set aside in the dark to settle for two days. Add 2 min. of hydrochloric acid, shake up, and again allow to digest for 24 hours. Now pour the emulsion into a shallow porcelain tray to set. When thoroughly set, cover with distilled water for one or two hours. Pour off the water, and flood with 5 gr. tannin, 2 gr. gallic acid, 2 dr. acetic acid, and 1 oz. water.

The emulsion should remain submerged for three hours. It may then be placed in flowing water until no trace of acid remains. It should afterwards be consigned to folds of clean linen, and worked about until the water has been expressed. It may now be dried at a low temperature, and preserved in a light-proof bottle.

Pellicle so made may be dissolved for use in a mixture of 1 oz. ether and 1 oz. alcohol. Plates coated with this emulsion, and dried in a warm dark room, are ready for use, and should be developed with alkaline pyrogallic acid as in the tannin process, and fixed with soda hyposulphite. Collodion-emulsion plates are more sensitive than dry collodion plates that have been washed and coated with a preservative. Intensification may be effected as with the wet process.

Gelatine Emulsion Process.—The manufacture of gelatine emulsion is one of the most recent advances in photography, and marks a new era in its history. Its introduction has rendered it possible to obtain portraits and views in the fraction of a second. Pedestrians in the streets, trains at express speed, birds on the wing, may be caught on the gelatine dry plate.

In making gelatine emulsion, the reagents required are the same as those employed in the collodion process, with this difference, that gelatine takes the place of collodion.

The manufacture of this emulsion is hedged round with difficulties, arising out of the instability and impurity of gelatine, and the rapidity with which it is decomposed by atmospheric conditions over which the chemist has no control.

It is imperative that great care be observed in selecting a suitable gelatine. Cognet's gelatine is in many respects best fitted for the purpose, but it has one great defect, small particles of grease are locked up in its flakes. These make their presence known in opaque spots in the finished plates. Nelson's "No. 1 photographic gelatine" is, on the whole, the safest to employ. Having fixed upon this gelatine, the next operation is working out the combining proportions of the haloid salts and silver nitrate, so as to leave the bromo-iodide in excess. Free silver nitrate is fatal to the process. The following is a reliable formula:—(*a*) 600 gr. gelatine, 330 gr. ammonium bromide, 10 gr. ammonium iodide, 7 oz. water; (*b*) 600 gr. silver nitrate, 7 oz. distilled water.

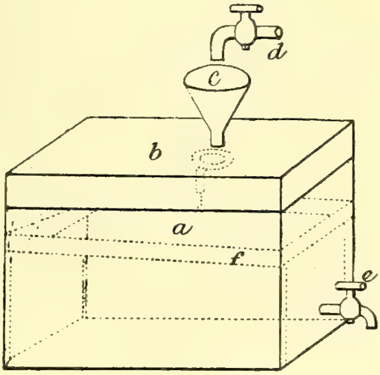
Of the above gelatine, take 500 gr. only, add to this the bromo-iodide salts and 7 oz. of water. Allow the gelatine to swell for 15 minutes, after which, place the jar containing the gelatine and salts in a hot-water bath at 71° (160° F.). Dissolve the silver nitrate in its allotted water, and raise to 82° (180° F.). Add the silver drop by drop to the gelatine solution, stirring vigorously until the last drop is taken up. Place the emulsion thus formed with its porcelain jar in a light-proof pan (an ordinary tin saucepan) half full of water, and boil for 20 minutes. Allow to cool down to about 38° (100° F.), and after swelling the remaining gelatine, add it to the boiled emulsion. Place the whole in a cool place to set. When thoroughly set, the jelly may be turned out of the jar on to a square of strong netting (preferably silk), having meshes about ⅛ in. in diameter. Spread a piece of fine white muslin over a wide basin filled with water. Gather up the netting, and force the emulsion through its folds into the water, beneath which is the sheet of muslin. This will part the jelly into thin shreds, and aid washing. The object of washing the emulsion is to get quit of the free salts in its composition, which would injure the process were they left in. It is best to employ a wooden washing-trough, Fig. 1093: *a* represents the trough; *b*, a light-proof lid; *c*, a funnel, with gas-pipe worm beneath to prevent light entering the tank; *d*, a water-tap to keep up a constant stream of water; *e*, a second outflow-tap to carry off the soluble salts which fall to the bottom of the water in the tank; *f*, a light frame, with muslin stretched across, in which the shreds of jelly rest while washing. Six or eight hours' flow of water is all that is required to fit the emulsion for use. During warm weather, ice should be placed in the water, and the feeding-funnel should be packed with ice, so as to keep the temperature below 10° (50° F.). After washing, run off the water through the lower tap, and allow the emulsion to drain for an hour or two.

The emulsion may now be scooped up with a glass spoon, and melted in a porcelain jar at 32°

(92° F.). This is best effected in a water-bath. The emulsion is now ready for coating the plates; 1 oz. of fluid should coat 1 doz. plates 4¼ × 3¼ in. All the operations described after mixing the salts with the silver must be conducted in the dark room. As a further security against light, the dark room should be illuminated by a paraffin lamp, enclosed in panels of ruby glass, covered outside with orange paper.

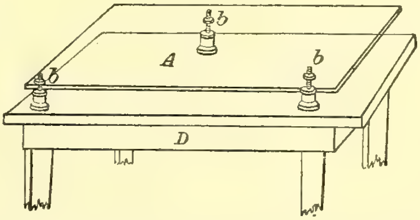
In coating the plates, it is necessary to employ a table of plate-glass (Fig. 1094) carefully levelled. The emulsion, when dissolved, should be passed through a sieve of fine muslin, to remove grit and mechanical impurities. It should then be decanted into a wide-mouthed bottle, half covered at the mouth with a membrane of muslin, which intercepts air-bells in pouring on to the plate. The addition of 2 oz. of alcohol to the pint of emulsion will cause it to flow more freely over the plate, and the plate to dry more rapidly when set. When the emulsion has been poured over the plate, spread with a glass rod, and the excess drained off, the plate may be placed upon the level table to set. When set, it should be reared up in a rack to dry. Under favourable conditions, drying will be completed in 8 hours.

1093.



Plates made by this process are so rapid as to render the use of the "drop shutter" necessary for out-door work. It must be understood, however, that what is termed "instantaneous photography" is only possible under favourable conditions of light and atmosphere. It is impossible to set down any arbitrary rules to guide photographers in timing exposure of gelatine or any other plates. So much depends on the conditions under which photographs are taken. For instance, plates prepared by the above formula may prove at one time more rapid than at another, owing to the emulsion being boiled for a longer or a shorter time, or to the salts being mixed at a higher or a lower temperature. The focal length of the objective, and the size of the diaphragm employed, as well as the light under which the photograph is obtained, are all factors to be taken into account in determining duration of exposure.

1094.



Assuming that the plate has been properly timed in the camera, it may be developed with the following alkaline pyro-solution:—(*a*) 6 gr. pyrogallic acid, 2 oz. water; (*b*) 1 oz. ammonia liq., 2 oz. distilled water, 60 gr. potassium bromide. Place the exposed plate in a shallow ebonite or porcelain tray, film uppermost, pour over solution *a*, and see that the plate is quite submerged. Drop into a glass measure four to six drops of *b*; pour back *a* into the measure, and again flood the plate by pouring back the developer. The negative will soon appear, and should be fully developed in half a minute. Wash off the developer, and fix in 5 oz. soda hyposulphite, and 10 oz. water. After fixing, wash thoroughly with water, and then consign the negative to a saturated bath of common alum, which should remain for 5 minutes. Again wash and rear up to dry. Heat must not be applied in drying, otherwise the gelatine will run. Drying may be greatly aided by pouring methylated spirit over the plate; when draining, it carries the water with it.

Intensify the negative, if necessary, with 20 gr. pyrogallic acid, 25 gr. citric acid, 6 oz. water. When required for use, to 1 oz. of this, add 4 min. nitric acid, and 20 of a mixture of 30 gr. silver nitrate, 1 oz. distilled water. This is best effected after the negative is dry, and thoroughly freed from hyposulphite, when it must be moistened in a tray of water, and the solution be poured over. The operation must be conducted in the dark room. When fully intensified, wash off, dry, and varnish, as in the wet collodion process. The gelatine plate, when dry, may be heated without risk of injury.

Retouching Negatives.—Although retouching is a sort of pseudo-art, and has nothing to do with the scientific phase of photography, it is nevertheless important, seeing that a poor negative by dint of pencilling, may be made to produce fair prints. A really good negative may also be improved by a few well-placed touches of the retoucher's pencil.

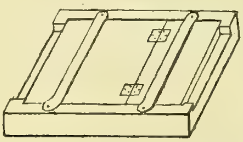
The negative to be dealt with should be set upon a table-easel, furnished with a white reflector, which throws the light up through the negative, revealing its flaws and defects. The varnish on the negative should be perfectly hard and dry. The portion to be retouched should be rubbed with the soft point of the finger, and a little finely-powdered pumice, so as to impart a tooth to the surface. The pencils used, HB and BB, should be sharply pointed. With the first, if it be a portrait-negative that is on the easel, touch out freckles or transparent spots on the face. With the BB, come lightly over the hard shadows about the mouth, nose, and eyes. But above all things, care must be taken not to overdo retouching, as it is apt to interfere with the true character of the face. Artistic perception, and a kindly appreciation of character, are valuable attributes in the professional retoucher.

Printing-processes.—Printing of positives from negatives may be divided into two classes. The first, which still finds many adherents, is based on the blackening of silver salts by the aid of light. Prints produced by this method are liable to fade. The second class includes all the modern processes, which secure permanency in the finished prints.

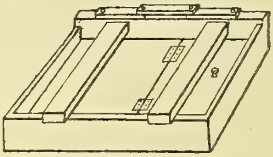
In ordinary silver-printing, the paper required is generally albuminized and salted ready for the silver-bath. This paper is best procured from a dealer. It may even be purchased sensitized, ready for the printing-frame.

To prepare the ordinary albuminized salted paper, pour into a flat dish a solution of 50 gr. silver nitrate, and 1 oz. distilled water. The sheet of paper to be sensitized is lifted, face downwards, by the two diagonal corners, and lowered on to the solution, beginning at the bend in the centre, and steadily lowering until the sheet lies flat on the surface. By this means, air-bubbles are expressed. About four minutes is sufficient to impregnate the salted surface, after which, lift a corner of the paper, and pass a glass rod beneath. Draw the paper over the rod, to get rid of superfluous moisture, and pin up to dry in the dark room. When dry, the paper is placed in contact with the negative in the printing-frame, film to film. Perfect contact is established by the pressure-frame, Figs. 1095, 1096. Now expose to light until the print is somewhat darker than required when finished. The print should be taken out and trimmed to size round the edges, the cuttings being preserved to recover the silver.

1095.



1096.



Toning the Print.—Place the print in water, to wash out the free silver; change the water several times, until no trace of milkiness is observed. Immerse the print in a bath of 1 gr. gold chloride, 4 gr. soda bicarbonate, and 8 oz. water, to be used immediately after being made up; or 1 gr. gold chloride 25 gr. soda acetate, and 8 oz. water, to be made 24 hours before being used. The red colour of the washed prints will speedily give place to a darker purpled hue, which must be a trifle darker than what is required for the finished print. Remove from the toning-bath, and wash; then immerse the print in 1 oz. soda hyposulphite, and 6 oz. water. The print should remain for 20 minutes in the fixing-solution, after which, it should be washed in running water for several hours.

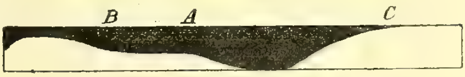
The positive, after washing, may be pressed between folds of blotting-paper, and, while damp, brushed over with a paste made of ordinary starch. Place the picture on its card mount, cover with a sheet of clean paper, and press down.

Yellow stains on the prints are caused by touching the albuminized surface with fingers soiled with soda hyposulphite. When the bath contains too little silver, it will dissolve the albumen. When the bath becomes brown, add 1 dr. powdered kaolin, shake up, and filter. The hyposulphite bath should be used only once.

Albuminized Sensitive Paper.—After salted albuminized paper has been sensitized, it may be preserved in its sensitive state, without discolouring, for several months by rendering the paper acid with citric acid. When the silver solution has been applied, and while the paper is still damp, float on a bath composed of 6 gr. citric acid and 1 oz. water. The paper should be taken from the acid bath as soon as possible, and hung up to dry. By increasing the proportion of acid, the keeping qualities are improved, but the paper should be neutralized by ammonia fumes before placing in the printing-frame.

Permanent Positive Printing.—Carbon Printing.—Theoretically, the process of carbon printing is simple; practically, it is difficult, and demands technical knowledge, and careful treatment in all its details. A principle, extremely rudimentary in itself, underlies all printing processes in which carbon or permanent pigment is used. It is that gelatine charged with potassium bichromate, when dried and exposed to white light, becomes insoluble. In addition to the bichromate in the photographic film of gelatine, it carries a powdered pigment in a fine state of division. This film, when exposed to light under a negative, is rendered insoluble, in a ratio corresponding with the lights and shadows of the negative. The deep shadows of the picture become quite insoluble while the high lights remain unchanged and perfectly soluble. Fig. 1097 represents a transverse section of the carbon film. The light passing through the clear parts of the negative has penetrated through the film at A. This point represents the deepest shadow, and most insoluble position of the film. At B, the light has pierced midway through the film, where the half tones of the negative have interposed. The film at C remains in its normal condition, no light having passed through. This point answers to the high lights of the negative. By immersing the film, so printed, in warm water, the gelatine and pigment will dissolve out at C, partly at B, and remain intact at A. In this manner, a positive print is obtained in low relief, the deepest shadow being represented at A, and highest light at C. But the pigmented film when supported on a white ground, by virtue of its semi-transparency, discloses a visible picture, having all the gradations of light and shadow of the negative from which it has been printed. The quantity of pigment held by the gelatine is so adjusted as to yield perfect opacity in the parts only where it has been most affected by the light.

1097.



Carbon-tissue, like albuminized paper, has become an article of commerce, and may be procured of almost any colour. Its preparation involves technical difficulties so grave as to render it inadvisable for photographers to attempt to make the tissue for themselves. It will be sufficient in the present instance, therefore, simply to outline the method by which it is manufactured.

The paper designed to carry the tissue must be tough, smooth, and not too heavily sized. Suitable paper is made in rolls by Rives, Stienback, and other manufacturers. The gelatine should neither be too soluble, nor too hard. It must be free from fat, chalk, acid, and alum. The gelatine should be rendered flexible by the addition of soap and sugar. Indian-ink, or other suitable colouring matter in a fine state of division, is next provided. All colours whose permanency is doubtful should be avoided. The basis must be carbon. This may be mingled with Indian red, oxide of iron, alizarine, purpurine, umber, indigo, Vandyke brown, Venetian red, bone-black, and so on. The gelatine and pigment, when mixed in proportions suitable for the sort of tissue required are consigned to a tank, and kept at a given temperature. The roll of paper to be coated is passed over the surface of the fluid at an accurately adjusted speed. The paper thus takes on a uniform coating. The speed at which this operation is carried through regulates the thickness of the coating. The roll with its film is passed into a drying-chamber, kept at a uniform temperature, and scrupulously free from noxious fumes. When dry, the tissue has the appearance of American cloth, or patent leather.

Sensitizing Carbon-Tissue.—The dry tissue cut the required size, is immersed in 1 oz. of potassium bichromate and 50 oz. distilled water. This may be done in a metallic tray, several sheets being immersed at a time, and care taken to remove air-bubbles from the surface of the tissue. The sheets should remain until they have become limp and flat, after which, they may be removed with wooden or bone forceps, as the potassium bichromate is poisonous. Each sheet, as it is brought out, should be placed face down on a plate of clean glass, and an indiarubber squeegee passed over the back, to remove superfluous moisture. This done, the tissue may be fixed to wooden clips, and hung up to dry in a dark room, free from dust.

The proportion of potassium bichromate should be varied to suit the season of the year, and the character of the negative to be printed. In warm weather, a weak bath should be used. When the negative is hard, the bath should be strengthened. A strong solution yields soft prints, whereas with a weak bath, satisfactory results are obtained from a weak negative.

In timing the exposure of a carbon print, it is necessary to use a photometer, as the tissue undergoes no visible change during the process of printing. The photometer consists of a square box, having a lid with a slit, and beneath, a ribbon of sensitized albuminized paper. The slit is formed in a coating of brown paint on a disc of glass set into the lid. When in use, the end of the ribbon is brought beneath the slit, and the box is closed. The photometer is then placed beside the printing-frame. The sensitized paper will speedily darken in the light, and assume the tone of the brown paint. Thus one tint is registered, and the ribbon is moved, so as to present a new surface in the slit.

By dint of practice, the number of tints required to print a negative is ascertained to a nicety, so that the process may be repeated successfully.

The ordinary printing-frame may be used in this process, although special frames are constructed for printing ovals and tinted margins to " card " and " cabinet " photographs.

It is essential in printing carbon-tissue to attach a narrow mask of blank or orange paper to the edges of the negative, so as to leave a margin all round the print unaffected by light.

Single Transfer.—Carbon prints by single transfer require reversed negatives; with ordinary negatives, the prints will be reversed. Reversed negatives are made in a variety of ways. By the aid of a mirror in front of the camera-objective, reversed negatives may be taken direct. They may also be obtained by the "dusting-on" process. Obernetter's formula is 1 dr. dextrine, 1¼ dr. white sugar, ½ dr. ammonium bichromate, and 3 oz. water. A glass plate is coated with this solution, drained, and dried over a spirit-lamp. It is then placed in contact with the negative, and printed in diffused light in 15–20 minutes. The plate is then laid on a sheet of white paper, and dusted over with a broad soft brush, charged with finely-powdered graphite. The print develops gradually with repeated dusting. Should the image develop at once, and indistinctly, the exposure has been too short; if on the other hand, the image is thin and full of detail, exposure has been unduly prolonged. After development, the reversed negative is coated with thin collodion, and may be placed in the printing-frame.

Another method of multiplying and reversing negatives is first to print, from the negative, a carbon positive on glass, and from this, print reversed negatives with carbon-tissue. Negatives may also be enlarged and reversed by taking a transparency from the original negative, through the camera, using either wet collodion or a gelatine dry plate. When a print is obtained on carbon-tissue from a reversed negative, it is damped in cold water, and laid face downwards on a sheet of thin transfer-paper. The paper is first laid upon a sheet of glass, the squeegee is then passed over the back of the tissue, and perfect contact is effected between tissue and paper. When squeegeeing, it is well first to cover the back of the tissue with a sheet of waterproof cloth. In about 20 minutes, the tissue and its support may be transferred to a tank of water, heated to about 35° (95° F.). The original paper on which the tissue was made will soon lift at the edges, and come away, leaving the film on the transfer-paper. All the parts unaffected by light will dissolve off, and by moving the print about, the picture will soon appear. Development must be continued until all the details of the picture are fully out, when the print may be finally washed by changing the water, and plunged into a bath of 1 oz. alum and 4 oz. water. It may then be hung up to dry. The object of placing a safe edge round the negative is to secure the perfect adhesion of the film to its support when developing. Were there no such margin, and the picture printed up to the edge of the negative, the tissue would curl up, and leave the transfer-paper. Should the print be over-exposed, warmer water should be used in development; if under-exposed, colder water.

Double Transfer Process.—Ordinary—not reversed—negatives are required for the double-transfer process. Here a waxed and collodionized glass plate takes the place of the transfer-paper employed in the method just described. A plate of glass of the finest quality should be selected, and coated with a solution of 20 gr. pure bees'-wax and 30 oz. pure benzol. The plate is levelled, and the solution is spread over the surface with a broad soft brush; then drained off, and polished with a piece of old silk, taking care not to remove too much of the wax.

Coat the plate with plain collodion, and when the film has set, plunge into a bath of cold water, and wash until the film is uniformly wet. The exposed tissue having been damped and rendered pliable, may be squeegeed down to the collodion. When this is being done, the plate should be well covered with water, and the tissue, bent up at the ends, be laid down first in the middle, and steadily lowered to the sides. After the lapse of 15 minutes, the print may be developed on its glass support.

Suitable transfer-paper is easily procured from the Autotype Co., of London, or other makers. This paper (which is enamelled) should be soaked in cold water for ½ hour, or until it becomes soft. Transfer the paper to a bath of water heated to 49° (120° F.). When the surface becomes slimy, the glass transparency and support are dipped into cold water, and the transfer-paper is laid down on its surface. It is next covered with waterproof cloth, and squeegeed into close contact. When dry, by passing a knife round the edge, the picture may be lifted from the glass, and will have a highly polished surface. In order to retain the full brilliancy of the print, it should be mounted by first trimming the edges of the picture on the glass plate, coated with warm starch or dextrine. Thin cardboard or white paper, after being damped, is laid over the back, and squeegeed down. Two or three thicknesses may be superposed, each being coated with starch. The print with its backing is then allowed to dry, after which, it may be removed from the glass support. The glaze may be retained by trimming the print after it has left the glass plate, and coating its edges only with hot starch, and, after mounting, placing it under pressure until dry.

Double transfer may be effected by using zinc plates, or ground-glass plates, by coating with wax, and omitting the collodion film.

Polished zinc imparts a glazed surface to the print, whereas ground-glass yields mat prints.

A flexible support for double transfer has been patented by J. R. Sawyer, and is supplied by the Autotype Co., of London. It is coated with gelatine rendered insoluble by means of alum.

The support requires to be waxed, and the prints dealt with in detail, in much the same way as in the methods already described.

The Woodbury Process.—The Woodbury process, like the carbon process, is based upon the action of light upon gelatine charged with potassium bichromate.

A solution of gelatine, prepared with a slight admixture of Indian-ink and potassium bichromate, is spread upon a plate of glass, and dried. When dry, the gelatine film is removed from the glass, printed, and developed, as in the carbon process. By this means, a relief is obtained. This is laid upon a perfectly flat, polished, and hard-tempered plate of steel. A plate of type-metal is then laid upon the relief, and the whole is passed between the parallel jaws of a hydraulic engine. When taken from the press, it will be found that the type-metal is impressed with a perfect reverse, or intaglio, of the relief. In other words, the leaden plate has taken the true level of the steel, the divergence from the level surface is caused by the relief, the lights of the picture being represented by the highest relief, and the shadows by the depressions in the plate.

The success of the process hinges upon the steel plate being perfectly level, and on the same conditions being observed in the construction of the press for subsequent printing. In the Woodbury photographic press, a sheet of thick plate-glass is laid upon the leaden intaglio, and the upper iron plate of the press, covered with hot cement, is let down upon the glass, which adheres to the cement.

In this manner, two parallel plains are obtained, the lower one formed by the intaglio, and the upper by the plate-glass. The next stage in printing requires that the intaglio should be slightly greased, and covered in the centre with a warm solution of semi-transparent gelatine and Indian-ink. A sheet of hard-pressed, smooth, white paper, is next laid on the ink, and the upper lid of the press is brought down, and locked. The superfluous gelatine is thus expressed, the portion left in the mould sets in 2–3 minutes, and the resulting proof is a permanent pictorial relief in Indian-ink. The high lights of the photograph have been pressed out by the projections in the intaglio, leaving the white paper exposed; while the semi-transparent jelly ascends in beautiful gradations, attaining its highest relief, and therefore its greatest opacity, in the deepest shadows. The relief is low, and when dry, the surface of the print appears to be perfectly flat. As in carbon printing, so in this process, a wide range of colour may be employed in preparing the printing-ink.

It is a purely mechanical process after the relief has been printed from the negative, and, on that account, is extremely useful in producing large numbers of prints without the aid of light. Thousands of copies may be pulled from one impression, and the number obtainable from a single gelatine relief is almost incredible.

Collotype Printing.—Collotype printing also owes its origin to the mingling of chromium salts with gelatine, but it differs from kindred processes in the principle upon which it is based. Here it is not a question of the solubility or insolubility of the gelatine film, so much as of chemical affinity. The collotype plate, after exposure in the printing-frame, is treated much in the same way as a lithographic stone. When damped over with a wet sponge, the parts unaffected by light absorb water, while the parts affected repel water, and have an affinity for fatty ink. To enter into the process more fully, two squares of plate-glass are ground together with fine emery until they are obscured. Take one of the plates, wash, and coat with 4 oz. albumen and 20 gr. ammonium bichromate. The albumen must first be beaten into a froth, and allowed to settle. Test the solution, and neutralize with dilute ammonia; coat the plate, and dry by heat at 35° (95° F.). Expose the plate to daylight long enough to print an ordinary silver positive. Wash the plate in water for ten minutes, and again dry. Coat with 1 oz. gelatine, 1 dr. potassium bichromate, and 20 oz. water. Dry by heat as before, and apply a third coating of 1 oz. gelatine (hard), 20 oz. water, 3 oz. alcohol, 100 gr. ammonium bichromate, and 15 gr. calcined magnesium. Add to this solution, just before using, 5 gr. chrome alum and ½ oz. water. Coat on a levelling-stand, and dry by heat not exceeding 38° (100° F.).

After the plate thus prepared has been printed under the negative, sponge over with water, blot off excess of moisture, and ink with a roller as in the lithographic process.

The pigment in the ink must be in a fine state of division, and rendered fluid by the addition of oil of turpentine. If the exposure of the plate has been properly timed, a positive impression in printing-ink will develop under the roller, and may be pulled off on paper in a collotype press. The plate, indeed, should yield some hundreds of proofs of uniform quality.

There are a number of methods of utilizing the properties developed by the exposure to light of bichromatized gelatine. By some methods, reliefs are obtained, and electrotyped in metal, or cast in type-metal. Copies of line engravings and drawings are thus made on a reduced or an enlarged scale, and worked with the text in ordinary printing. Some examples of this process may be seen in Tissandier's 'History and Handbook of Photography.'

Ceramic Photographs.—Encaustic photographs may be produced in a variety of ways. A secret method is practised, and excellent results obtained, by using carbon-tissue. The tissue is prepared by a special process, which obviates any risk of the gelatine cracking up during the baking of the enamel.

Another method is the "dusting-on" process, previously alluded to. But in place of employing graphite in developing the image, a finely-powdered encaustic colour is used. An exhaustive account of this process is given in the 'Photographic News Almanac' for 1881.

The substitution process is one by which the finest results are obtained. It consists in copying a negative through the camera on a wet collodion plate. But the silver of which this positive is made up, were it left in the film where burnt in, would yield a sickly-yellow picture. It is, therefore, necessary to treat the silver positive with a solution of salts of platinum or iridium, until the silver has been transformed into chloride and replaced by metallic platinum or iridium. After the chloride of silver has been removed in the fixing-butt, the picture may be transferred to its support and fired.

The collodion positive must be developed with protosulphate of iron; the image must be dense, approaching opacity in the shadows, and perfect transparency in the highest lights. When washed after fixing, it is detached from the edges of the plate by a penknife, and placed in water acidulated with sulphuric acid. This hardens the film, and it may then be floated off the glass. It is next washed free from acid in several changes of water. The film is then transferred to a solution of 2 dr. platinum chloride, and 1 oz. water. Neutralize with soda bicarbonate, then acidulate with one or two drops of nitric acid. Here the film should repose until the image is black, after which, it is fixed in 3 dr. soda hyposulphite and 1 oz. water. Again wash, and transfer the film to a basin of clean water. Place the enamelled plate beneath the film, with the collodion side next the enamel; float into position, and lay down with a fine camel-hair brush, excluding air-bubbles.

After burning in, the enamel is glazed with a flux made up of 8 parts powdered glass, 5 nitre, and 6 flint. A thin solution of indiarubber in benzol should be used as a varnish to the enamel, and the flux dusted over this, and burned in.

Platinotype Printing.—Permanent prints are obtained on paper by this process. A sheet of paper is coated with a solution of platinum chloride and iron oxalate. After the paper has been dried and exposed under a negative, a faint image is observed. This image develops into a rich black, by immersing the print in a solution of oxalate of potash, heated to 77° (170° F.). An acid water-bath is all that is required for fixing the image.

Applications of Photography.—A number of the ordinary applications of photography have already been incidentally noticed; but, in conclusion, it is necessary to catalogue other important uses to which photography has been applied. Its widest and most popular range of usefulness is found in ministering to the wants of all classes of society, and even providing the poorest families with picture galleries in miniature. But its sphere is ever widening, and its utility being demonstrated in a thousand different ways.

Apart from portrait and landscape work, the following are among the principal applications of photography:—

Reproducing works of art in permanent pigments; reproducing maps, plans, architectural and mechanical drawings, engravings, and manuscripts, by photo-engraving, photo-lithography, and collotype printing; photographs for book illustration, printed in permanent ink by Woodbury-type, collotype, and carbon process; encaustic photographs, Woodbury-type, and carbon transparencies, for art and decorative purposes; micro-photography, by means of which, microscopic objects are enlarged for book illustration, and for educational purposes in class-rooms; photo-micrography has been successfully employed in reducing official despatches, charts, newspapers, &c., to dimensions so small as to admit of their being placed in a quill, and transported by carrier pigeons to besieged cities in time of war; photographing columns of water raised by torpedoes; balloon-photography, by which photo-surveys are obtained of an enemy's country; astronomical photography, employed in photographing sun, moon, stars, and their spectra; photography in the hands of chemists has proved of the greatest service in spectrum analysis, and in investigating the phenomena of interference of the rays of the spectrum.

Photography in colour remains to be discovered, little or no progress having yet been made in this direction. It has been proved that certain colours of the solar spectrum may be reproduced on a sensitive photographic plate, and that certain other colours make no impression on the film. Having got thus far, there can be no reasonable doubt that a polychrome system of photography will be ere long discovered—a system which shall admit of the photographing of natural objects in all their varied hues. Development may be looked for in other directions as well, in the extended application of the art-science to the requirements of art education, and in its application to science. The day, indeed, may not be distant when photo-telegraphy may become an accomplished fact, when it will be possible to telegraph a portrait from one continent to another.

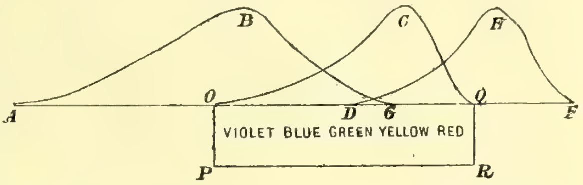
(See Printing and Engraving.) J. T.

PHOTOMETRY (Fr., *Photométrie*; Ger., *Lichtmessung*).

"Photometry" (light-measurement), or the comparison of the visible intensities of different lights among each other, is a term usually restricted to the intensity of the light in question as it affects the eye of the observer, and does not include a determination of the chemical intensity of light, which, as is well known, does not coincide with what may be called its luminosity; nor does it embrace any measurement of the intensity of the heat accompanying the light under examination.

It is a fact familiar to photographers that the most sunny days are not those on which their chemicals "work quickest," i. e. are most powerfully affected by light, some of the comparatively dull days in March, for example, being more suitable for photographic work than much brighter days later in the year. This want of coincidence between the chemical, luminous, and heating maxima in the spectrum, or coloured band produced by the decomposition of white light when passed through a prism, is illustrated in Fig. 1098, which is not, however, a representation of the spectrum of any particular light, but a typical diagram. O P R Q represents the visible part of the spectrum; the curve O C Q shows the intensity of the eye-apparent light, with a maximum over the yellow part of the spectrum; the intensity of the heat-rays is shown by curve D E F, with a maximum just outside the red end Q R; while the chemical intensity is indicated by the curve A B G, with a maximum near the violet end of the visible spectrum. The heat-measurements are usually made with a delicate thermo-electric pile, while we are indebted chiefly to Professors Bunsen and Roscoe for methods of measuring the chemical intensity of light.

1098.



In constructing photometers, or instruments for measuring the comparative brightness of two or more lights, it must be borne in mind that the human eye cannot judge directly, with any approach to accuracy, of the relative intensity of two lights, although it can determine readily whether two shadows are of equal intensity, or whether two similar surfaces of equal extent are equally brightly illuminated. The other principle involved in the use of photometers is the law that when two shadows of the same object, produced by different lights, are equally intense, or when two similar surfaces are equally illuminated, the intensities of the two lights producing this effect vary directly as the squares of their distances from the screen. Thus, if a lamp at 2 ft. and a candle at 1 ft. from the screen produced the same shadow or illuminated surface, since the square of 2 is 4, and the square of 1 is 1, the relative intensities of the two would be as 4 to 1, i. e. the lamp would be of "4-candle power."

It is necessary to fix upon some standard, in terms of which the brightness of any given light may be expressed. Various standards have been proposed at different times, such as lamps of a definite construction, burning oil of a fixed quality at a given rate per hour—for example, the French carcel lamp, or better, Parker's hot-oil lamp, but it has been found that the most uniform or least variable standard of illumination, is a wax (or spermaceti) candle, size 3 to the lb., with a wick of 27 or 28 threads of the best Turkey cotton, and burning at the rate of 125 gr. an hour. It is a candle of this kind that is referred to in speaking of gas as "16-candle," or of an electric light as of 400-candle or 6000-candle power. The standard for gas-testing, as fixed by Act of Parliament, is a sperm candle burning at the rate of 120 gr. an hour, or 2 gr. a minute. In the best photometers, as will be seen presently, the standard light is fixed upon a balance, so that its rate of burning may be constantly checked.

Before proceeding to describe the various kinds of photometers, it may be useful to consider briefly two remarkable results of careful photometric observation, which have an important practical bearing upon the most economical arrangement of a number of separate lights, whether they be candles, lamps, or gas-flames, i. e. the arrangement which will give the greatest total amount of light from the various illuminating sources.

The first is that when the flames of two lamps or candles touch each other, the luminous intensity of the combined flame is greater than the sum of the intensities of the separate flames. This effect was first observed by Dr. Benj. Franklin, and appears to be due to the increased temperature at the part where the flames overlap.

This fact has been taken advantage of by W. Sugg, in the construction of those combinations of 2, 3, or 4 flat-flame gas-burners, now so much used in the standard lamps placed at the intersections of streets, and other important points in many large English and Colonial towns. The gas-argand burner is also an extreme instance of the kind, the ring there being made up of a series of round-hole jets, each single flame of which overlaps the flame on either side of it.

The second result may be thus expressed:—A comparison of the amounts of light afforded by the same number of flames in different relative positions proves that flame is perfectly transparent, and thus that the luminous effect of a row of lights is the same whether this arrangement is parallel with or perpendicular to the direction of the rays; similarly a flat gas-flame gives the same degree of light in all directions.

The chief forms of photometer will now be described. The simplest, most readily constructed, and most easily used, is that known as Rumford's. It consists merely of a black cylindrical rod mounted vertically upon a stand or foot, and of a white screen upon which to receive the shadows of the rod. The lights to be compared (all others should be put out) are placed about until the respective shadows cast by the rod are of equal depth. The distances of the lights from the screen are then carefully measured, and each number thus obtained is multiplied by itself. The proportion between these products represents the relative intensities of the lights under examination. For example, suppose lamp A at 21 in. and lamp B at 30 in. from the screen gave equally deep shadows, then, since 21 × 21 = 441, and 30 × 30 = 900, lamp A is to lamp B as 441 to 900, or nearly as 1 to 2, or, in other words, lamp B gives twice as much light as lamp A. As a similar calculation has to be made in all photometric tests (though it is frequently assisted by previously constructed tables suited to each instrument), it will not be repeated.

Bunsen's photometer depends on the equal illumination of two surfaces, and is much more exact than the preceding. The principle of it, with very slight modifications, is adopted in the delicate photometers used in gas-testing. The essential part of it is a piece of thin paper stretched in a frame, and the paper is rendered semi-transparent by being saturated with a solution of spermaceti in turpentine-oil, with the exception of a central spot about 0·75 in. in diameter, which is allowed to remain opaque. In using it (in a dark room), the standard light is placed behind the spot, and the variable one in front. When the two surfaces are equally illuminated, the opaque spot disappears, and the whole surface of the disc is perfectly homogeneous in appearance.

Wheatstone's photometer consists of a small silvered polished bead, mounted upon a stem to which a looped motion is given by appropriate clockwork. When it is placed between two sources of light, and the clockwork is set in motion, two looped curves of different brightness are seen, so very close together that their intensities can readily be compared; the lights are then adjusted to give curves of equal brightness, and their respective distances are read off. The formation of a luminous curve by a moving bright bead, depends, of course, upon the well-known principle of "persistence of vision," the simplest illustration of which is the circle of fire traced by a lighted stick whirled round by hand.

Letheby's and Evans's photometers are similar in construction, and both depend upon the principle of Bunsen's. Letheby's consists essentially of a long bar, at each end of which are supports for a light, one being the standard candle upon a Keates's candle-balance. Upon the rod, slides a box, with holes on each side and in front; it contains the semi-transparent paper with the opaque spot. The box is moved until the spot disappears, when a pointer attached to the box indicates on a scale the intensity of the unknown light in terms of the standard. Evans's is a similar instrument, but the box is fixed, and the lights move along the bar.

In gas-testing, one or other of these instruments is usually employed, with a great number of adjuncts, such as gas-meters, pressure-gauges, &c., &c. The gas is burnt at the rate of 5 cub. ft. an hour in a No. 1 Sugg's London Argand for 14- to 16-candle gas, and in a Sugg's No. 7 steatite bat's-wing, for cannel gas. Many precautions have to be taken to correct the meter as to the rate of burning. Observations are taken every minute for ten minutes, and an average of the whole is taken as the result. A "jet photometer" is used as a rough and ready test in gas-works; it depends on the fact that, to maintain a flame or jet at a constant height (from a given circular orifice), the poorer the gas in quality, the greater is the pressure of gas required. This pressure can be delicately measured, and, with the aid of tables, can be translated into illuminating power in candles.

Sugg's new "patent illuminating-power meter" depends upon an extension of this principle.

The Dispersion Photometer.—When very intense lights, such as the oxy-hydrogen, the magnesium, or the electric, have to be compared with gas or candles, it would be very inconvenient to remove the stronger light to the necessary distance (50 ft. or more) from the screen. This difficulty has been ingeniously overcome by passing the intense light through a concave lens, thus dispersing it, and lessening its intensity. The curvature and focal length of the lens being known, the amount of dispersion is easily calculated, and this dispersed light, with its intensity thus diminished to a known extent, is employed in the photometer. In the case of the electric light, it is usual to make two observations, one through green, the other through red glass.

Jansen has just constructed a photographic photometer, consisting of a frame with a sensitized plate, before which, and in the path of the light-rays to be measured, a screen with triangular perforations is made to pass. A gradation of shade, decreasing from the base of the triangles towards the apex, is thus obtained, and points of equal shade indicate equal intensity. It is stated that he has in this way been able to express the illuminating power of some of the stars in terms of that of the sun, and it is expected that he will be able to construct a definite solar scale, to which all artificial lights may be referred.

The recent wonderful researches of Alex. Graham Bell, assisted by Tainter, upon sounds produced when beams of light, interrupted rapidly by perforated discs revolving at high speed, fall upon various substances, seem to point to the possibility of constructing an instrument in which the different intensities of two lights will make themselves evident in differences of audible tones, when the rays from each of them fall upon suitably constructed receivers containing lamp-black, and provided with hearing tubes to convey to the ear the sounds produced by the successive impact of interrupted light-rays.

Illuminating Value.—In order to arrive at a true estimate of the actual money-value of any illuminating material, it is necessary to take into account not merely its light-intensity, as determined by the photometer, but also the rate at which it burns, and its price (per lb.). There are therefore three variable elements, each one of which must be duly considered. If, for example, paraffin and stearine (or composite) candles give equal light photometrically, and 1 lb. of stearine candles lasts 48 hours, while 1 lb. of paraffin lasts 54 hours (146 gr. and 129 gr. per hour respectively), it is obvious that if the stearine candles cost 8*d.* a lb., and the paraffin cost 8¾*d.*, the paraffin is really the cheaper of the two, and at 9*d.* would cost the same.

Some writers throw this calculation into the form of "cost per 100 of light," where the 100, or standard, is taken from a standard "hot-oil" lamp, burning every hour 815 gr. of oil, or 0·1164 lb. at 11*d.* a lb. Hence in this case, the cost per 100 of light is $0{\cdot}1164 \times 11 = 1{\cdot}2804d.$ Comparing this with a wax candle, burning 125 gr. an hour, giving only $\frac{1}{11}$ the light of the lamp, and costing 2*s.* 6*d.* or 30*d.* a lb., we have as the cost per 100 of light,—

$$125 \times 11 = 1375 \text{ gr., or } 0{\cdot}1964 \text{ lb.} \times 30 = 5{\cdot}892d.$$

Proceeding in this manner, Dr. Frankland has drawn up the following tables of illuminating equivalents, or the quantities of different illuminating materials necessary to produce the same amount of light:—

Young's paraffin-oil	1·00 gal.	Sperm candles	22·90 lb.
American petroleum, No. 1 ..	1·26 „	Wax „	26·40 „
„ „ No. 2 ..	1·30 „	Composite „	29·50 „
Paraffin candles	18·60 lb.	Tallow „	36·00 „

Taking into account the market prices of these various materials, he concludes the comparative cost of the light, equal to that of 20 sperm candles (each burning for 10 hours at 120 gr. an hour), to be:—

	s.	*d.*		*s.*	*d.*
Wax	7	2½	American petroleum	0	6½
Spermaceti	6	8	Young's paraffin-oil	0	5
Paraffin	3	10	Coal-gas	0	4¼
Tallow	2	8	Cannel-gas	0	3
Sperm-oil	1	10			

It may be remarked, in passing, that the difference in favour of gas, as against candles, is very much reduced in practice, since users of gas always habituate themselves to a much more intense light than when they employ candles. Probably the same thing will obtain, *mutatis mutandis*, when domestic electric lamps are substituted for gas.

Taking into account the cost of material, its rate of consumption, its market price per lb., and its light-power, Peclet gives the following valuable table, upon the data that:—1 pint of oil costs 5*d.*; 1 lb. tallow candles, 7*d.*; 1 lb. wax candles, 2*s.* 2*d.*; 1 lb. stearine candles, 1*s.* 4*d.*; 100 ft. coal-gas, 7*d.*; 100 ft. oil-gas, 2*s.* 3*d.*; and that 1000 ft. coal-gas = 44½ lb. sperm, or 51 lb. stearic acid, or 6½ gal. colza-oil, or 5·9 gal. sperm-oil.

Means of Illumination.	Intensity of the Light.	Consumption of Illuminating Material per Hour.	Illuminating Power: Carcel's Lamp = 100.	Price of 100 grm. of Illuminating Matter.	Cost of the Light per Hour.	Cost of a Light of the same Intensity per Hour.
				d.	*d.*	*d.*
Tallow candles, 6 to the lb. ..	10·66	8·5	54·04	1·5	0·125	1·169
Wax „ 6 „ ..	14·60	9·6	61·57	5·0	0·461	3·155
Stearine „ 5 „ ..	14·40	9·3	66·58	3·2	0·298	2·066
Kitchen lamp	6·65	8·0	33·60	1·4	0·083	1·246
Flat-wick lamp	12·50	11·0	47·50		0·114	0·912
Astral lamp	31·00	26·7	48·70		0·280	0·893
Sinumbra lamp	56·00	37·1	63·00		0·385	0·687
Inverted reservoir lamp	90·00	43·0	87·8		0·446	0·495
Hydrostatic lamp	45·00	17·26	109·2		0·179	0·398
Carcel's lamp	100·00	42·00	100·0		0·435	0·435
Vapour „	130·70	151·00	36·2	1·3	2·013	1·207
		cub. ft.		Per 1000 cub. ft.		
Coal-gas	127·00	8·70		7·0	0·580	0·456
Oil-gas	127·00	2·43		19·2	0·630	0·367

(See Candles; Gas [Coal]; Oils—Illuminating Values.) W. L. C.

PIGMENTS AND PAINT.

Pigments (Fr., *Pigments*; Ger., *Farben*).—The term "pigments" is applied to those colouring matters which are mixed in a powdery form with oil or other vehicle for the purpose of painting. They differ in this respect from the dyestuffs (see Coal-tar Products, pp. 641–684, and Dyestuffs, pp. 854–869). Their preparation for use and their application are described hereafter in the section on Paint (see pp. 1552–1556); the present article embraces only their origin and production. A very large proportion of the pigments are derived from the mineral kingdom. Organic colouring matters for use as pigments are mostly made in the form of "lakes," by one of the three following methods:—(*a*) To a filtered solution of the colouring matter, is added a solution of alum; the whole is agitated, and the colour is precipitated by a solution of carbonate of potash. (*b*) A solution of the colouring matter is made in a weak alkaline lye, and precipitated by adding a solution of alum. (*c*) Recently-precipitated alumina is agitated with a solution of the colouring matter as before, until the liquid is nearly decolorized, or the alumina assumes a sufficiently deep tint. The first method is generally adopted for acidulous solutions of colouring matter, or those injured by alkalies; the second, for those not injured by alkalies; the third, for those whose affinity for gelatinous alumina enables them to combine with it by mere agitation. (See Alumina, p. 333.)

It will be convenient to describe pigments under the heads of the chief colours, in alphabetic order—blacks, blues, greens, reds, whites, and yellows.

Blacks.—See article Blacks, pp. 452–456.

Blues. *Cobalt Blue.*—A mixture of 8–10 parts alumina, freshly precipitated and freed from water, and 1 part arseniate or phosphate of cobalt, slowly dried, and heated to dull redness.

Paris Blue.—(*a*) A thorough mixture of 2 parts sulphur and 1 part dry carbonate of soda is gradually heated in a covered crucible to redness or till fused; a mixture of silicate of soda and aluminate of soda is then sprinkled in, and the heat is continued for an hour; the little free sulphur present may be washed out by water. (*b*) An intimate mixture of 37 parts China-clay, 15 parts sulphate of soda, 22 parts carbonate of soda, 18 parts sulphur, and 8 parts charcoal, is heated in large crucibles for 24–30 hours; the mass is re-heated in cast-iron boxes at a moderate temperature till the desired tint appears, and is finally pulverized, washed, and dried. (*c*) Gently fuse 1075 oz. crystallized carbonate of soda in its water of crystallization; shake in 5 oz. finely-pulverized orpiment, and, when partly decomposed, as much gelatinous alumina hydrate as contains 7 oz. anhydrous alumina; add 100 oz. finely-sifted clay, and 221 oz. flowers of sulphur; place the whole in a covered crucible, and heat gently till the water is driven off, then to redness, so that the ingredients sinter together without fusing; the mass is then cooled, finely pulverized, suspended in river-water, and filtered. The product is heated in a covered dish to dull redness for 1–2 hours, with occasional stirring. Colourless or brownish patches may occur, and must be removed.

Prussian Blue.—(*a*) A solution of 2 parts alum and 1 part sulphate of iron is made in water; a solution of yellow prussiate of potash is then acidulated with sulphuric acid, and some of the first solution is dropped in till the precipitate falls slowly; the latter is well washed on a filter, and dried. (*b*) Mix a solution of protosulphate of iron with one of red prussiate of potash; wash and dry.

Saxon Blue.—Dissolve 1 oz. sulphate of iron and 8 oz. alum in 1 gal. water; add separate solutions of prussiate of potash and pearlash, until the precipitation ceases; collect the precipitate after some time; wash thoroughly, and dry.

Ultramarine.—The preparation of ultramarine from the gem lapis lazuli (see Gems, p. 1042) no longer survives. Artificial ultramarine, of which, some 10,000 tons are made annually, is composed approximately of 46·60 per cent. silica, 23·30 alumina, 3·83 sulphuric acid, 21·48 soda, 1·06 peroxide of iron, and traces of lime, sulphur, and magnesia. The ingredients employed are sometimes China-clay, sulphate of soda, charcoal or pit-coal, and rosin; or China-clay, soda, silica, sulphur, and rosin. Their proportions are a matter of secrecy, but may be deduced pretty accurately from the percentage composition just given. The raw materials are ground very fine, well mixed, pressed into muffle-furnaces, and calcined at a red heat for 12–36 hours, or until the sulphur is nearly burnt off. When the firing is complete, the furnaces are closed tightly, and the material is allowed to cool, requiring 5–6 days. The product is green ultramarine, which is then roasted with finely-powdered sulphur in pans under the influence of the air. After washing, it is ground in wet mills for 2–5 days, settled under the action of heat, repeatedly washed, classified, dried, bolted, and packed.

Greens. *Baryta Green.*—Mix 2 parts caustic soda and 1 part chlorate of potash, and gradually add 2 parts very finely powdered manganese; heat gradually up to dull redness, then allow to cool, powder, and exhaust with water; filter and cool, and add a solution of nitrate of baryta to the filtrate. A violet-coloured baryta precipitate forms; this is carefully washed, dried, and treated with ½–1 part of caustic baryta, hydrated, and gradually heated up to redness, with constant stirring. The cooled mass is powdered, and finally washed to remove any excess of baryta.

Brighton Green.—Separately dissolve 7 lb. sulphate of copper and 3 lb. sugar of lead, each in 5 pints water; mix the solutions, stir in 24 lb. whiting, and when the mass is dry, grind to powder.

Brunswick Green.—(*a*) Pour 3 parts saturated solution of sal ammoniac over 2 parts copper-filings, contained in a vessel capable of being closed, and keep the mixture in a warm place for some weeks, when the newly-formed pigment is separated from the inoxidized copper by washing on a sieve; it is then washed with water, and slowly dried in the shade. (*b*) A solution of crude carbonate of ammonia is added to a mixed solution of alum and blue vitriol, as long as it affects it; in a short time, the precipitate is collected, washed, and dried. (*c*) Lighter shades are produced by the addition of sulphate of baryta, or alum.

Chrome or Guignet's Green.—Fuse together 3 parts boracic acid and 1 part bichromate of potash at a dull-red heat on the hearth of a flame-furnace. This forms a borate of chromium and potash, with evolution of oxygen. The mass is repeatedly washed with boiling water, which causes decomposition, and consequent separation of hydrated oxide of chromium and a soluble borate of potash. The oxide is washed, and ground very fine.

Emerald Green.—Form a paste with 1 part verdigris in sufficient boiling water, pass it through a sieve to remove lumps, and gradually add it to a boiling solution of 1 part arsenious acid in 10 parts water, the mixture being constantly stirred until the precipitate becomes a heavy granular powder, when it is filtered through calico, and dried.

Manganese Green.—Intimately mix 3–4 parts caustic baryta moistened with water, 2 parts nitrate of baryta, and 2 parts oxide of manganese; place in a crucible heated to dull redness, fuse, pour out, pulverize, digest in boiling water, wash in cold water, and dry in an atmosphere free from carbonic acid.

Mountain Green.—(*a*) Native green carbonate or bicarbonate of copper is ground to powder, either with or without addition of a little orpiment or chrome yellow. (*b*) Add a solution of carbonate of soda or potash to a hot mixed solution of alum and sulphate of copper.

Prussian Green.—A mixture of Prussian blue and gamboge.

Sap Green.—(*a*) The juice of buckthorn berries (see Drugs, p. 795) is extracted by allowing them to ferment in wooden tubs for 7–8 days, and pressing and straining; a little alum is added to the juice, which is evaporated down to a suitable consistence, and run into bladders to dry and harden. (*b*) Mix 11 oz. powdered arsenious acid, 1½ lb. carbonate of potash, and 1 gal. boiling water; dissolve, filter, and add to another solution of 2 lb. crystallized sulphate of copper in 3 gal. water, producing 1½ lb. of pigment.

Scheele's Green.—Dissolve 1 part powdered white arsenic and 2 parts commercial potash in 35 parts boiling water; filter, and add the solution gradually, while still warm, to a filtered solution of 2 parts sulphate of copper, as long as a precipitate falls; wash with warm water, and dry.

Vienna or Schweinfurth Green.—(*a*) Dissolve 8 lb. arsenious acid in the least possible quantity of boiling water, and add it to 9–10 lb. verdigris in water at 48½° (120° F.) passed through a sieve; set aside the mixed ingredients till the mutual reaction produces the desired shade. (*b*) Dissolve 50 lb. sulphate of copper and 10 lb. lime in 20 gal. good vinegar, and add a boiling-hot solution of 50 lb. white arsenic as quickly as possible; stir several times, allow to subside, collect on filter, dry, and powder. The supernatant liquid is employed to dissolve the arsenic for the next lot.

Douglas' Green.—Barium chromate is precipitated by adding to a solution of barium chloride a sufficiency of a soluble chromate to effect complete separation; to the lemon-yellow chromate, is added 20 per cent. of strong sulphuric acid, which produces a deep-red by the liberation of chromic acid; the mass is then ground, and heated to redness, when it becomes green.

REDS. *Brazil-wood Lake.*—(*a*) Digest 1 lb. ground Brazil-wood in 4 gal. water for 24 hours, boil ½ hour, and add 1½ lb. alum dissolved in a little water; mix, decant, strain, add ½ lb. tin solution, again mix well, and filter; to the clear liquid, cautiously add a solution of carbonate of soda while a precipitate forms, avoiding excess; collect, wash, and dry. The shade will vary according as the precipitate is collected. (*b*) Add washed and recently precipitated alumina to a strong filtered decoction of Brazil-wood.

Carminated Lake.—(*a*) The cochineal residue left in making carmine is boiled with repeated portions of water till exhausted; the liquor is mixed with that decanted off the carmine, and at once filtered; some recently precipitated alumina is added, and the whole is gently heated, and well agitated for a short time; as soon as the alumina has absorbed enough colour, the mixture is allowed to settle, the clear portion is decanted, and the lake is collected on a filter, washed, and dried. The decanted liquor, if still coloured, is treated with fresh alumina till exhausted, and thus a lake of second quality is obtained. (*b*) To the coloured liquor obtained from the carmine and cochineal as just stated, a solution of alum is added, the filtered liquor is precipitated with a solution of carbonate of potash, and the lake is collected and treated as before. The colour is brightened by addition of tin solution.

Carmine.—Boil 1 lb. cochineal and 4 dr. carbonate of potash in 7½ gal. water for ¼ hour. Remove from the fire, and stir in 8 dr. powdered alum, and allow to settle for 20–30 minutes. Pour the liquid into another vessel, and mix in a strained solution of 4 dr. isinglass in 1 pint water; when a skin has formed upon the surface, remove from the fire, stir rapidly, and allow to settle for ½ hour, when the deposited carmine is carefully collected, drained, and dried.

Cochineal Lake.—(*a*) Digest 1 oz. coarsely powdered cochineal in 2½ oz. each water and rectified alcohol for a week; filter, and precipitate by adding a few drops of tin solution every 2 hours, till the whole of the colouring matter is thrown down; wash the precipitate in distilled water, and dry. (*b*) Digest powdered cochineal in ammonia water for a week; dilute with a little water, and add the liquid to a solution of alum as long as any precipitate (lake) falls. (*c*) Boil 1 lb. coarsely powdered cochineal in 2 gal. water for 1 hour; decant, strain, add solution of 1 lb. cream of tartar, and precipitate with solution of alum. By adding the alum first and precipitating the lake with the tartar, the colour is slightly changed.

Indian Red.—(*a*) Sulphate of iron is calcined until the water of crystallization is expelled, then roasted by a fierce fire until acid vapours cease to arise, cooled, washed with water till the latter has no acid reaction, and dried. (*b*) Calcine 11 parts common salt with 25 parts green sulphate of iron; well wash with water, dry, and powder. (*c*) The finest Indian red or "crocus" usually undergoes a second calcination at a higher temperature.

Madder Lake.—(*a*) Tie 2 oz. madder in a cloth, beat it well in a pint of water in a stone mortar, and repeat the process with about 5 pints of fresh water till it ceases to yield colour; boil the mixed liquor in an earthen vessel, pour into a large basin, and add 1 oz. alum dissolved in 1 pint boiling water; stir well, and gradually pour in 1½ oz. of strong solution of carbonate of potash; let stand until cold, pour off the yellow liquor from the top, drain, agitate the residue repeatedly in 1 qt. boiling water, decant, drain, and dry. (*b*) Add a little solution of acetate of lead to a decoction of madder, to throw down the brown colouring matter; filter, add solution of tin or alum, precipitate with solution of carbonate of soda or potash, and proceed as before. (*c*) Macerate 2 lb. ground madder in 1 gal. water for 10 minutes; strain and press quite dry; repeat a second and third time, and add to the mixed liquors ½ lb. alum dissolved in 3 qt. water; heat in water-bath for 3–4 hours, adding water as it evaporates; filter first through flannel, and when cold enough through paper; add solution of carbonate of soda as long as precipitate falls; wash the latter till the water comes off colourless, and dry.

Red Chalk or Reddle.—An earthy red hæmatite, found in all countries and most geological formations.

Red-lead.—This is prepared on the large scale by the oxidation of metallic lead in a reverberatory furnace with two fire hearths covered by an arched roof, situated at the extreme end, separated from the middle hearth, in which the lead lies, by fire-bridges, and fed with coke. The lead, about 10 per cent. being hard, is worked about by an iron tool as soon as melted, the "massicot" or protoxide formed being constantly pushed to the side. The temperature must be kept at low redness, or the oxide will melt. The treatment is sustained for 24 hours; the massicot is then removed, ground, and levigated, and again exposed in the furnace to the same heat for 48 hours, or till it exhibits a bright-red colour on cooling. The furnace is then closed, and allowed to cool as slowly as it will. The product is "minium" or "red-lead."

Vermilion.—(*a*) Melt 1 part sulphur, and gradually add 5–6 parts mercury, continuing the heat till the mixture swells up; then cover the vessel, remove it from the fire, and when the contents are cold, reduce to powder, and sublime in a closed vessel, so placed in a furnace that the flames reach about half the height. Gradually increase the heat till the lower part of the subliming-vessel becomes red-hot; break the cold sublimate, grind in water to fine powder, sift, and dry. It is a black sulphide of mercury. This, reduced to powder, and sublimed, gives a filamentous mass of violet hue, appearing scarlet on trituration. (*b*) Grind together 300 parts mercury and 114 parts flowers of sulphur for some hours, and gradually add 75 parts caustic potash dissolved in 450 parts water; continue the grinding for some time longer, and gently heat the mixture in an iron vessel, first stirring constantly, afterwards at intervals, keeping the temperature as nearly as possible at 46° (115° F.), and renewing the water as evaporated. When reddening commences, increased care is needed, and when the colour is nearly fine, the heat must be maintained at a lower degree till a rich colour is produced. Every precaution must be taken against inhaling the vapours. (*c*) To a mixture of 4 parts hyposulphite of soda and 4 parts sulphate of zinc in dilute solution, add drop by drop a solution containing 1 part corrosive sublimate. Heat the whole gently for 60 hours at 45°–55° (112°–130° F.).

WHITES. *Alum White.*—Dry mix 2 lb. powdered alum, 1 lb. honey; powder, calcine to whiteness in a shallow dish, cool, wash, and dry.

Chinese White.—Mix finely-ground zinc white into a cream with mucilage of gum tragacanth, grinding with a glass muller.

Permanent White.—Precipitate sulphate of barium from the chloride by adding dilute sulphuric acid.

Spanish White.—The softest and purest white chalk, elutriated, balled, and dried.

Sulphate of Lead.—Precipitate the pigment by adding dilute sulphuric acid to an acetic or nitric acid solution of litharge; wash and dry. The clear liquid may be used indefinitely.

Whiting.—Ground chalk, balled and dried.

White-lead.—White-lead or carbonate of lead is made by placing metallic lead in contact with acetic acid in open earthenware vessels, and covered with tan, a number of these vessels forming a "stack," and the whole remaining thus for about 11 weeks, when the lead becomes completely carbonized. The stack is then pulled down, and the carbonate of lead is ground and dried. Many mixtures of white-lead and chalk are sold under fanciful and misleading names.

Wilkinson's White.—Litharge is ground with sea-water till it ceases to whiten, and is then washed and dried.

Zinc White (Griffiths').—Chloride or sulphate of zinc is precipitated by means of a soluble sulphide—sodium, barium, and calcium sulphides have been used—and precautions are taken that no iron present is precipitated. The precipitate is collected, dried, and calcined for some time at cherry-red heat, with careful stirring. It is raked out while hot into vats of cold water, then levigated and dried. It is an oxysulphide of zinc.

YELLOWS. *Chrome Yellow.*—(*a*) Add a filtered solution of nitrate or acetate of lead to a filtered solution of neutral chromate of potash so long as a precipitate falls; collect this, wash with soft water, and dry in security from sulphur-tainted air. (*b*) Dissolve acetate of lead in warm water, and add sufficient sulphuric acid to convert it into sulphate; decant the clear liquid, wash the residue with soft water, and digest with agitation in a hot solution of yellow (neutral) chromate of potash, containing 1 part of this salt for every 3 parts sulphate of lead; decant the liquid, and drain, wash, and dry the precipitate.

Gamboge (FR., *Gomme Gutte*; GER., *Gutti, Gummigutt*).—Gamboge is a product of several trees of E. Asia: viz., *Garcinia Morella* var. *β. pedicellata* [*G. Hanburyi*], a native of Cambodia, the province of Chantibun in Siam, the islands on the E. coast of the Gulf of Siam, and the S. parts of Cochin China; *G. Morella*, growing in the moist forests of Ceylon and S. India; and *G. pictoria*, of S. India, by some considered identical with *G. Morella*. *G. travancorica*, of the southern forests of Travancore and the Tinnevelly Ghâts, is capable of affording small supplies of the pigment for local use, but not for export. (See also Resinous and Gummy Substances—Gamboge.)

When the rainy season has set in, parties of natives start in search of gamboge-trees, and select those which are sufficiently matured. A spiral incision is made in the bark on two sides of the tree, and joints of bamboo are placed at the base of the incision so as to catch the gum-resin as it exudes with extreme slowness during a period of several months. It issues as a yellowish fluid, but gradually assumes a viscous and finally a solid state in the bamboo receptacle. It is very commonly adulterated with rice-flour, and the powdered bark of the tree, but the latter imparts a greenish tint. Sand is occasionally added. The product from a good tree may fill three bamboo joints, each 18–20 in. long and 1½ in. in diameter. The trees flourish on both high and low land. Annual tapping is said to shorten their lives, but if the gum-resin is only drawn in alternate years, the trees do not seem to suffer, and last for many years. Dr. Jamie, of Singapore, who has gamboge-trees growing on his estate, says that they flourish most luxuriantly in the dense jungles. He considers the best time for cutting to be February–April. The filled bamboos are rotated near a fire till the moisture in the gamboge has evaporated sufficiently to permit the bamboo to be stripped from the hardened gum-resin. The gamboge is secreted by the tree chiefly in numerous ducts in the middle layer of the bark, besides a little in the dotted vessels of the outermost layer of the wood, and in the pith. It arrives in commerce in the form of cylinders, 4–8 in. long and 1–2½ in. in diameter, often more or less rendered shapeless. When good, it is dense, homogeneous, brittle, showing conchoidal fracture, scarcely translucent, and of rich brownish-orange colour. Inferior qualities show rough, granular fracture, and brownish hue, and are sometimes still soft. The pigment consists of a mixture of 15–20 per cent. gum with 85–80 per cent. resin. It reaches Europe from Cambodia by way of Bangkok, Saigon, and Singapore. The exports from Singapore in 1877 were 240 *piculs* (of 133⅓ lb.); from Bangkok in 1875, 346 *piculs*; from Saigon annually, 30–40 *piculs*. Saigon, in 1879, received 27 *piculs*, valued at 12*l.* a cwt., from Cambodia.

Naples Yellow.—(*a*) Mix 3 lb. powdered metallic antimony, 1 lb. oxide of zinc, and 2 lb. red-lead; calcine, grind fine, and fuse in a closed crucible; grind the fused mass to fine powder, and wash well. (*b*) Grind 1 part washed antimony with 2 parts red-lead to a stiff paste with water, and expose to red heat for 4–5 hours.

Orpiment or King's Yellow and Realgar.—See pp. 339–340.

Yellow Lakes.—(*a*) Boil 1 lb. Persian berries, quercitron-bark, or turmeric, and 1 oz. cream of tartar, in 1 gal. water till reduced to half; strain the decoction, and precipitate by solution of alum. (*b*) Boil 1 lb. of the dyestuff with ½ lb. alum in 1 gal. water, and precipitate by solution of carbonate of potash. (*c*) Boil 4 oz. annatto and 12 oz. pearlash in 1 gal. water for ½ hour; strain, precipitate by adding 1 lb. alum dissolved in 1 gal. water till it ceases to produce effervescence or a precipitate strain, and dry.

Paint (Fr., *Peinture*; Ger., *Anstrichfarbe*).—"Paint" consists essentially of two parts, (1) the vehicle or medium, and (2) the pigment (see Pigments). In the case of oil-paints, a third substance becomes necessary, to facilitate the drying or solidification of the vehicle; this is termed a "drier." A perfect vehicle should mix readily with the pigment, forming a mass of about the consistency of treacle. It should itself be colourless, and have no chemical action upon the pigments with which it is mixed. When spread out in a thin layer upon a non-porous substance, it should solidify, and form a film not liable to subsequent disintegration or decay, and sufficiently elastic to resist a slight concussion.

Unfortunately, we possess no vehicle which complies with all these conditions; those which most nearly approach them are the drying oils (see Oils and Fatty Substances, p. 1467). The use of oil in painting is said to have been invented in the 14th century, and, in a short time, it reached a considerable degree of perfection. We have only to compare a van Eyck with a painting by a modern master, Turner, for instance, to see that even the best of recent painters have not succeeded in giving to their works that durability which the originators of the method attained. All organic substances are liable to a more or less rapid oxidation, especially if exposed to light and heat. Oil is no exception to this rule; but it seems that, in its pure state, it is much more durable than when mixed with other substances. Although ground-nut- and poppy-oils (see pp. 1391, 1409) are sometimes employed by artists where freedom from colour is essential, yet linseed-oil (see p. 1393) is the vehicle of by far the larger proportion of paint used both for artistic and general purposes.

Oil-paint appears to have been unknown to the ancients, who used various vehicles, chiefly of animal origin. One of these, which was in high repute at Rome, was the white of eggs beaten with twigs of the fig-tree. No doubt the indiarubber contained in the milky juice exuding from the twigs contributed to the elasticity of the film resulting from the drying of this vehicle. Pliny was aware of the fact that when glue is dissolved in vinegar and allowed to dry, it is less soluble than in its original state. Many suggestions have been made in modern times for vehicles in which glue or size plays an important part. In order to render it insoluble, various chemicals have been added to its solution, such as tannin, alum, and a chromic salt. None of these vehicles, however useful for special purposes, has become sufficiently well known to warrant description here.

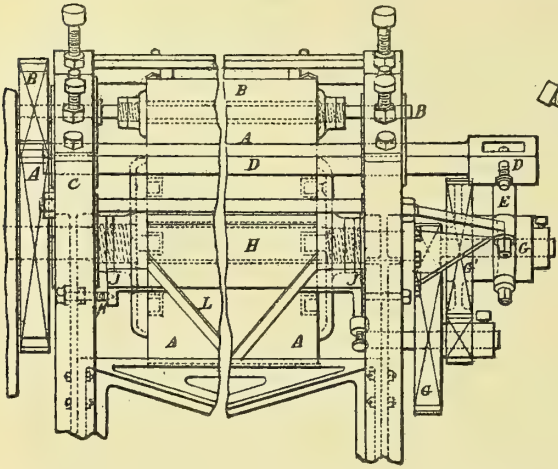
Linseed-oil, to be suitable for painting, must dry well. The test described in the article on Floorcloth (see p. 1002) will indicate whether this be the case or not. Another reliable test is to cover a piece of glass with a film of the raw oil, and to expose it to a temperature of about 38° (100° F.). The time which the film requires to solidify is a measure of the quality of the oil. If the oil has been extracted from unripe or impure seed, the surface of the test-glass will remain "tacky" or sticky for some time, and the same will happen if the oil under examination has been adulterated with either an animal or vegetable non-drying oil.

Until recently, linseed-oil was frequently adulterated with cotton-seed-oil (see p. 1385), extracted from the waste seeds of the cotton-plant. Where the admixture was considerable, it could easily be detected by the sharp, acrid taste of the cotton-seed-oil. Now, however, means have been found for removing this disagreeable taste, and the consequence has been that cotton-seed-oil is so largely used for adulterating olive-oil, or as a substitute for it, that its price has risen above that of linseed-oil. Another adulterant which is rather difficult to detect is rosin. Oil containing this substance is thick, and darker in colour than pure oil. When the proportion of rosin is considerable, its presence may be ascertained by heating a film of the oil upon a metallic plate, when the characteristic smell of burning rosin will be perceptible. When the percentage of rosin is too small for detection in this manner, a film of the oil should be spread upon glass and allowed to dry. When quite hard, the film should be scraped off, and treated with cold turpentine, which will dissolve any rosin which may be present, without materially affecting the oxidized oil. The presence of rosin may also be detected by the following simple chemical test. The oil is boiled for a few minutes with a small quantity of alcohol (sp. gr. 0·9), and is allowed to stand until the alcohol becomes clear. The supernatant liquid is then poured off, and treated with an alcoholic solution of acetate of lead. If the oil be pure, there will be but a very slight turbidity, while the presence of rosin causes a dense flocculent precipitate. Should linseed-oil be adulterated with a non-drying oil, it will remain sticky for months, when spread out in a thin film upon glass or any other non-absorbent substance.

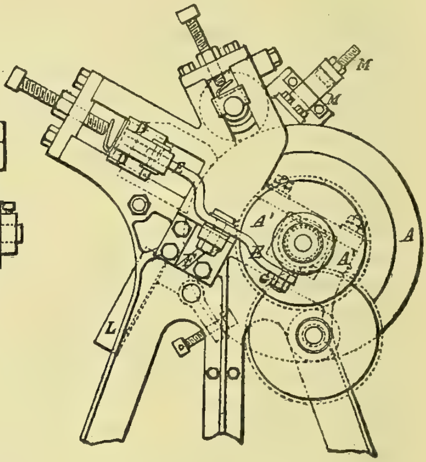
The sp. gr. of linseed-oil is, in some cases, of value in estimating its quality; but, as the variations are slight, it would be difficult to detect them in so thick a liquid by means of an ordinary hydrometer. A simple method of obtaining an approximate result is to procure a sample of oil of known good quality, and to colour it with an aniline dye. A drop of this tinted oil will, when placed in the oil to be tested, indicate, by its sinking or swimming, the relative density of the liquid under examination. Freshly-extracted linseed-oil is unfit for making paint. It contains water and organic impurities, respecting the composition of which little is known, and which are generally termed "mucilage." By storing the oil in tanks for a long time, the water and the greater part of the impurities are precipitated, forming at the bottom of the cistern a pasty mass known as "foots." To accelerate the purification of the oil, and to remove at least a portion of the colouring matter, various methods are in use. The action of sulphuric acid upon linseed-oil is not so favourable as upon other oils. It is, however, sometimes employed, in the proportion of 2 parts of a mixture of equal volumes of commercial sulphuric acid and water to 100 parts of oil. The dilute acid is poured gradually into the oil, and the mixture is violently agitated for several hours. It is then run into tanks, and allowed to settle. A concentrated solution of chloride of zinc has been substituted for sulphuric acid in the proportion of about 1½ per cent. of the weight of the oil. When the reaction is complete, steam or warm water is admitted into the liquid, in order to clarify it. Oil treated in this way loses a considerable proportion of the colouring matter which it originally contained. When the oil is to be used for white paint, it is sometimes bleached by exposing it to the action of light. On a large scale, this is done by placing it in shallow troughs, lined with lead and covered with glass. The lead itself appears to have some influence upon the bleaching of the oil, for the decoloration is not so rapid if the troughs be lined with zinc. For small quantities, a shallow tray of white porcelain or earthenware, similar to those in use for photographic purposes, gives very good results, the white surface increasing the photo-chemical action. It is not quite clear whether the presence of water accelerates the bleaching of oil by this method; some manufacturers consider its presence necessary, others omit it. Various salts are added to the water, the one most in use being copperas. (See also Oils and Fatty Substances, p. 1461.) However the oil may have been prepared, it will, if kept for a long time, deposit a sediment. At first, this contains mucilage; but the sediment from old oil consists chiefly of the products of decomposition of the oil itself. The presence of oxygen is not necessary for this decomposition; but it is increased by the action of light. Raw linseed-oil dries more slowly than boiled; but the resulting film is more brilliant and durable. Raw and boiled oil are therefore usually mixed in proportions varying according to the time which can be allowed for the paint to dry, or to the properties required of the film. For the ordinary kinds of paint, equal parts of boiled and raw oils are customary. Linseed-oil heated to a temperature of 176½°–204½° (350°–400° F.) dries much more rapidly than in its raw state. The maximum of drying power is, however, obtained by the addition of certain metallic oxides, which not only part with some of their own oxygen to the oil, but also act as carriers between the atmospheric oxygen and the heated liquid. This heating of the oil with oxides is known as boiling, although the liquid is not volatilized without decomposition, as is the case with water. At about 260° (500° F.), bubbles begin to rise in the oil, producing acrid, white fumes on coming into contact with the air. The gas thus given off consists chiefly of vapour of acroleïn mingled with carbonic oxide. There is no advantage in heating the oil to a higher temperature than 176½° (350° F.). Accurate experiments have shown that the drying properties of the oil are not increased by heating it beyond this point, while its colour is considerably darkened. For the finer qualities of boiled oils, it is essential that the raw oil should have been stored for some time, so that it may be free from mucilage. This mucilage is the chief source of the dark colour of some boiled oils; when heated, it forms a brown substance, which is soluble in the oil itself, and extremely difficult to remove. The oxides usually added to the oil during boiling are litharge or red-lead, the former being preferred on account of its lower price. About 2–5 per cent. by weight of the oxides or driers is gradually stirred into the oil after it has been slowly raised to a temperature of about 149° (300° F.). The stirring should be continued until the litharge is dissolved, or it would cake on the bottom of the pan, and cause the oil to burn. Litharge may even be reduced to a cake of metallic lead when the fire is brisk. Some pans are furnished with stirrers and gearing by which the latter can be worked, either by hand or steam. The material of which the pans are made is either wrought- or cast-iron. Copper pans are sometimes used with the object of improving the colour of the oil. Little is known respecting the chemical reactions which take place during the boiling of oil. Even when the air is excluded during the process, the drying properties are greatly increased, and, if boiled long enough, the oil is converted into a solid substance. The loss of weight which ensues is dependent upon the temperature, and the time during which the operation continues. It is less when the air is freely admitted than if the pan is covered with a hood. The vapours given off by the oil are of an extremely irritating character, and should be destroyed by passing them through a furnace. As their mixture with air in certain proportions is explosive, this furnace should be situated at some distance, and the gases be conducted into it by means of an earthenware pipe. (See also Oils and Fatty Substances, p. 1449.)

T. Holmes' apparatus for grinding pigments is shown in Figs. 1099 and 1100. The granite roller A revolves against a feed-roller B, travelling in the opposite direction, and at a lower speed, by which means, A feeds itself with the material to be ground. The roller A also works against a concave granite block D, to which is communicated a slow reciprocating motion in a direction parallel with the axis of the roller, thus assisting the grinding and equalizing the wear. A "doctor" cleans the surface of A as the pigment accumulates upon it. Brinjes and Goodwin's machine is shown in Figs. 1101, 1102, and 1103. The oil and pigments having been measured or weighed, are placed in the trough *h*. This is provided with stirrers, similar to those in a pug-mill, which are driven by means of the pulley *l*, *m* being a loose pulley; by shifting the strap on to this, the machine can be stopped at once. When the oil has been thoroughly incorporated with the pigment, the mixture is allowed to run through the spout *g* on the roller *a*. Working against *a*, is a second roller *b*, and this in its turn bears upon a third roller *c*. In order to prevent the grooving of the faces of the rollers, which always takes place when they revolve in the same plane, there is an arrangement by which a slight lateral motion is communicated to *b*, in addition to the rotary motion. A pin fixed upon the rigid bracket *k* works in the grooved cam *i*, which is keyed on the shaft of the roller *b*. The grinding power of the machine is considerably increased by this modification. The rollers are worked from the pulley *d*; the loose pulley *e* receives the strap when a pause in the working of the machine becomes necessary. The details of the construction of the grinding-machine are given in Fig. 1103. The rollers *a b c* are constructed of granite or porcelain; for fine grinding, the latter substance is preferable. They are adjusted by means of the screws *g h*. These are furnished with spiral springs, so that should a nail or other hard substance get between the rollers, these can rise in their bearings, letting the nail fall down at the back. The "doctor" or scraper *f* removes the paint from the surface of the roller *c*;

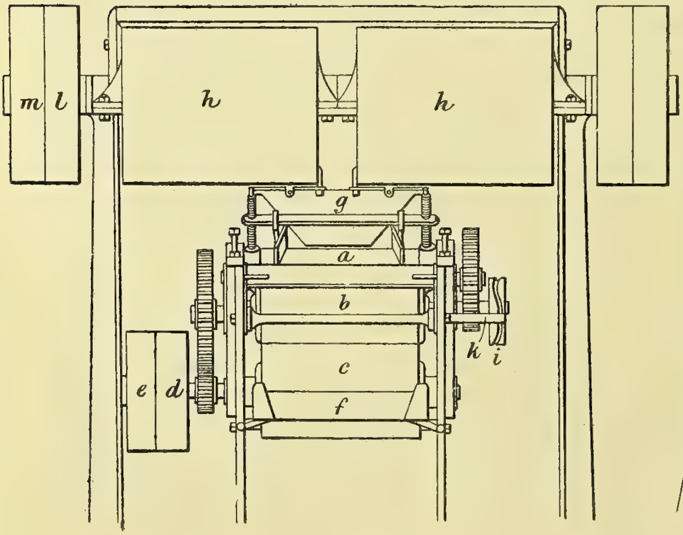
1099.



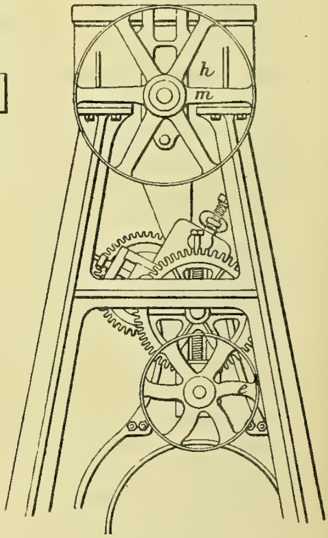
1100.



1101.

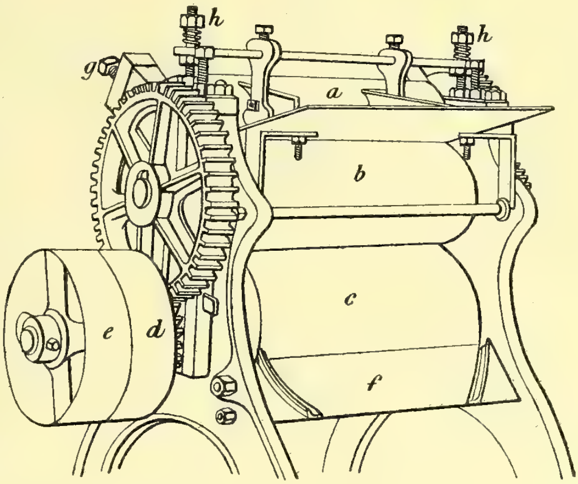


1102.



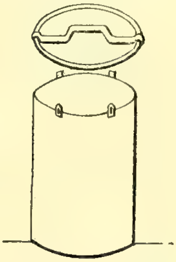
a b are also provided with smaller scrapers, which remove any paint that may cake upon their surfaces. Where extreme fineness is requisite, the paint is again passed through the machine, and this operation is sometimes repeated several times.

1103.



In working these or any other form of grinding-rollers, great care must be taken to clean them thoroughly immediately after use. If the paint be allowed to dry upon the surface of the rollers it is difficult of removal, and interferes with the perfect action of the machine. Should the working parts become clogged with solidified oil, a strong solution of caustic soda or potash will remove it. By means of the same solutions, porcelain rollers may be kept quite white, even if used for mixing coloured paints. Although the colour of most pigments is improved by grinding them finely in oil, yet there are some which suffer in intensity when their size of grain is reduced. Chrome red, for instance, owes its deep colour to the crystals of which it is composed, and when these are reduced to extremely fine fragments, the colour is considerably modified.

1104.



When paint is not intended for immediate use, it is packed in metallic kegs. The construction of these, as made by B. Noakes & Co., is shown in Fig. 1104. For exportation to hot climates, the rim of the lid is sometimes soldered down, a practice which effectually prevents access of atmospheric oxygen. White-lead paint is frequently packed in wooden kegs; these prevent the discoloration sometimes caused by the metal of iron kegs. When paint is mixed ready for use, it will, if exposed to the air, become covered with a skin, which soon attains sufficient thickness to exclude the atmospheric oxygen, and prevent any further solidification of the oil. The paint may be still better protected by pouring water over it, or it may be placed in air-tight cans. If it has been allowed to stand for some time, it must be well stirred before using, as the pigments have a tendency not only to separate from the oil, but also to settle down according to their specific gravity.

Of whatever nature the surface may be to which the paint is to be applied, great care must be taken that it is perfectly dry. Wood especially, even when apparently dry, may on a damp day contain as much as 20 per cent. of moisture. A film of paint applied to the surface of wood in this condition prevents the moisture from escaping, and it remains enclosed until a warm sun or artificial heat converts it into vapour, which raises the paint and causes blisters. Moisture enclosed between two coats of paint has the same effect. Paint rarely blisters when applied to wood from which old paint has been burnt off; this is probably due to the drying of the wood during the operation of burning. The first coat of paint applied to any surface is termed the "priming-coat." It usually consists of red-lead and boiled and raw linseed-oil. Experience has shown that such a priming not only dries quickly itself, but also accelerates the drying of the next coat. The latter action must be attributed to the oxygen contained in the red-lead, only a small portion of which is absorbed by the oil with which it is mixed. The drying of paint is to a great extent dependent upon the temperature. At a temperature below the freezing-point of water paint will remain wet for weeks, even when mixed with a considerable proportion of driers; while if exposed to a heat of 49° (120° F.), the same paint will become solid in a few hours. The drying of paint being a process of oxidation, and not evaporation, it is essential that a good supply of fresh air should be provided. When a film of fresh paint is placed with a certain quantity of air in a closed vessel, it does not absorb the whole of the oxygen present; but after a time, the drying process is arrested, and the remaining oxygen appears to have become inert. Considerable quantities of volatile vapours are given off during the drying of paint; these are due to the decomposition of the oil. When the paint has been thinned down by means of turpentine, the whole of this liquid evaporates on exposure to the air. There must, therefore, be a plentiful access of air, both to remove the vapours formed, and to afford a fresh supply of active oxygen. The presence of moisture in the air is rather beneficial than injurious at this stage. Especially in the case of paints mixed with varnish, moist air appears to counteract the tendency to crack or shrink. Under the erroneous impression that the drying of paint is a species of evaporation, open fires are sometimes kept up in freshly-painted rooms. It is only when the temperature is very low, that any benefit can result from this practice; as a rule, it rather retards than hastens the solidification of the oil, which cannot take place rapidly in an atmosphere laden with carbonic acid. The first coat of paint should be thoroughly dry before the second is applied. Acrylic acid is formed during the oxidation of linseed-oil, and unless this be allowed to evaporate, it may subsequently liberate carbonic acid from the white-lead present in most paints, and give rise to blisters. Sometimes a second priming-coat is given; but usually the second coat applied contains the pigment. This, as soon as dry, is again covered by another coat, and subsequently by two or more finishing-coats, according to the nature of the work. Before the first coat is applied to wood, all holes should be filled up. The filling usually employed is ordinary putty. This, however, sometimes consists of whiting ground up with oil foots of a non-drying character. When the films of paint are dry, the oil from the putty exudes to the surface, causing a stain. The best filling for ordinary purposes is whiting ground to a paste with boiled linseed-oil. For finer work, and for filling cracks, red-lead mixed with the same vehicle may be employed. There is no advantage in laying on the paint too thickly. A thick film takes longer to dry thoroughly than two thin films of the same aggregate thickness. Paint is thinned down or diluted with linseed-oil or turpentine. The latter liquid, when used in excess, causes the paint to dry with a dull surface, and has an injurious effect upon its stability. Sometimes the last coat of paint is mixed with varnish, in order to give it greater brilliancy. In this case, special care must be taken that the previous coats have thoroughly solidified, or cracks in the final coat may subsequently appear. The same remark applies when the surface of the paint is varnished. The turpentine with which the varnish is mixed has a powerful action upon the oil contained in the paint, if the latter is not thoroughly oxidized. The exterior of the paint is thus softened, and the varnish is enabled to shrink and crack, especially in warm weather.

The method of applying paint by means of brushes is too well known to need description; but a few words as to the proper treatment of the brushes may not be superfluous. The bristles are frequently fastened together by means of glue or size, which is not perceptibly acted upon by oil, and if brought into contact with this liquid alone, there would be no complaints of loose hairs coming out and spoiling the work. It is a common practice to leave the brushes in a paint-pot, in which the paint is covered with water to keep it from drying. The brushes are certainly kept soft and pliant in this way; but at the same time the glue is softened, and the bristles come out as soon as the brush is used. After use, brushes should be cleaned, and placed in linseed-oil until again required, when they will be found in good condition. Treated in this way, they will wear so much better that the little additional trouble entailed is amply repaid.

W. F. R.

POTTERY (Fr., *Poterie*; Ger., *Töpferwaare*).

The order in which the branches of the subject will be treated is as follows:—Definition and General principles; Raw Materials and their Preparation; Throwing-wheels and Lathes; Kilns or Ovens, and Muffles; the various Wares—Fire-ware, Stone-ware, Earthen-ware, Terra-cotta, Tiles, Porcelain, and China; Processes of Decoration.

Definition and General Principles.—Every ware made of clay, or of a mixture in which clay is the chief ingredient, and hardened by heat, may be regarded as a species of "pottery." There are many varieties of clay (see Clay, pp. 635–40), all of which have been formed by the disintegration of felspathic and silicious rocks, and consist of hydrous aluminic silicate mixed with small and varying proportions of other materials derived from the same sources. A clay adapted to the manufacture of pottery must be plastic, and must become hard under the influence of heat. Plasticity is an attribute of hydrous aluminic silicate, and is developed by the mechanical mixture of this body with a limited quantity of water. Clay is insoluble in water, but may be diffused through it in a state of extreme subdivision, and regains plasticity when the excess of water is removed. If a clay be exposed to a high temperature, artificially produced, and be rendered anhydrous by the removal of water previously held in chemical combination, it can never regain plasticity by mechanical mixture with water.

Hardening is produced (1) by the removal of water mechanically mixed with the clay, (2) by the removal of water, and sometimes of carbonic acid, chemically combined with the clay, (3) by the closer juxtaposition of the particles of the clay, due to the fusion of a part of the ingredients. Some clays, when exposed to the full heat of a pottery-kiln, fuse readily throughout their substance, owing to the presence of other materials in addition to the aluminic silicate. Aluminic silicate is by itself practically infusible, but when exposed to an intense heat in the presence of free silica, together with calcic, sodic, potassic, magnesic, ferric, or ferrous oxides, it unites, wholly or in part, with the silicates formed from these ingredients, to create a readily fusible glass. Most natural clays contain free hydrous silica, together with one or more of the oxides mentioned, and the quantity of aluminic silicate which can be rendered fusible is determined by the quantity of silicate-forming ingredients incorporated with it. Felspar, which is a natural glass, and from whose decomposition, certain clays are formed, is built up of equivalent parts of aluminic silicate and of potassic, sodic, or calcic silicate. The fusibility of a clay is greater or less as its composition approaches or recedes from the proportions observable in felspar.

Solidification necessarily implies contraction. Pure aluminic silicate, when artificially heated, shrinks excessively, and splits into fragments. The purest clays are the most infusible, and at the same time are the most liable to fracture and distortion under the influence of heat. Very few clays in their natural state are free from intermixture with iron. The form in which iron commonly appears is that of the yellow or brown hydrous ferric oxide. The presence of iron in an unburnt clay is often concealed by organic colouring matter; but exposure to a moderate heat destroys the organic matter, and discovers the pink or red colour of the anhydrous ferric oxide.

Certain impure natural clays may be employed in the manufacture of the coarsest descriptions of pottery, coherency being produced either by the plasticity of the clay and the simple removal of mechanically mixed water, as is the case in oriental sun-baked ware; or by the removal of both mechanically and chemically mixed water, together with the incipient fusion of part of the ingredients, provided these results are attained at a low temperature. Resistance to high temperatures, regularity of form, impermeability, purity of colour, and translucency can only be gained by the use of mixtures so constituted that the qualities, which are not supplied by the natural clay, are yielded by materials artificially introduced. A perfect mixture must be sufficiently plastic, when water is added, to facilitate manipulation; sufficiently infusible to resist collapse by fusion, when exposed to the heat requisite to produce hardness; sufficiently stable to resist excessive shrinkage and distortion; sufficiently fusible to become impermeable, and, in some cases, translucent; and sufficiently free from iron when the colour obtained from iron is not wanted, to be colourless or almost colourless after burning. A mixture for pottery is at the best a well-balanced mechanical arrangement, and cannot be regarded or represented as a chemical compound.

The value of the separate materials depends as much upon physical aggregation as upon chemical composition, and their qualities must be determined both by analysis and by direct experiment. Analyses and experiments must be constantly repeated, inasmuch as the materials consist principally of natural products, and not of artificially produced chemicals. As the mixtures for different wares must vary according as the physical or chemical natures of the raw materials vary, recipes and even analyses of wares are of little practical use. For white or light coloured goods, as well as for those intended to withstand high temperatures, pure clays are used. The distortion and fracture, due to excessive or irregular shrinkage, to which wares made from pure clays are especially liable, may be considerably reduced by the introduction of an infusible anhydrous substance, in such proportion as not to interfere materially with the plasticity of the clay. The substances employed are, for common ware, sand or a proportion of a grittier and less fusible clay; for fire-ware, graphite or burnt fire-clay; for domestic and sanitary ware, calcined flint; and for ornamental ware, baric sulphate or calcic phosphate. If a mixture be manipulated in a state of liquidity, and the resultant ware be brought to a vitreous condition by heat, the total shrinkage may amount to as much as 30 per cent. If wares are required to be impermeable or translucent, the infusibility of a pure clay, and the increase of infusibility caused by the introduction of an infusible foreign substance, must be compensated by the addition of a proportion of a glass-forming material of felspathic nature. By varying the proportion of this ingredient, wares may be obtained in every stage between porosity and translucency, and proportionately differing from or resembling glass in their physical properties.

The nature of wares depends in a great measure upon the temperature to which they are exposed. With a gradually increasing temperature, the same mixture may successively assume the texture and character of sun-baked ware, terra-cotta, stone-ware, porcelain, and glass. Intense and prolonged heat will convert the external crust of a Stourbridge-clay (see Clay) crucible into translucent porcelain. In artificial mixtures, the proportion of glass-forming ingredients is purposely kept so low that the surface of the ware, even after exposure to the full heat of the kiln, remains rough and absorbent. For most decorative, domestic, and sanitary purposes, it is necessary to cover this surface with a smooth, non-absorbent film; this result is practically gained by covering the surface of the ware with an extremely thin layer of glass. For certain common wares, whose composition renders them unfitted to resist a high temperature, and which would otherwise remain porous and incoherent, a film of glass serves the double purpose of a glaze and a bond.

Wares are coloured by metallic oxides. The common red, brown, and yellow tints are due to ferric oxide, whether naturally present or artificially introduced. The colours which may be obtained by the use of iron compounds depend upon the temperature to which the wares are exposed, the atmosphere in which they are burnt, and the constituents of the ware. If the temperature be low, and free access of air be permitted, the ware is tinted by the natural colour of the anhydrous ferric oxide; if, however, there be present an excess of calcic or magnesic oxides, the tints are greatly modified. If organic matter be present in large quantity, or if the ware be exposed to a strongly reducing atmosphere, the ware may be tinted black or grey, owing to the conversion of the ferric into magnetic oxide. At a high temperature, in an oxidizing atmosphere, and in the presence of glass-forming materials, the substance of the ware will be tinted yellow by the colour of the glass with which the ferric oxide has combined. If, however, the ferric oxide be reduced to the ferrous condition, the ware will be tinted green. All the metallic oxides which are used for colouring glass (see Glass, pp. 1083–4) may be used for pottery. If the temperature be low, or if no glass be formed in the ware, it will be coloured by the natural colour of the anhydrous oxide; if, on the other hand, the temperature be high, and if a glass be formed, the ware will receive the same colour as a glass would receive under similar circumstances. Advantage is taken of this fact to neutralize, by the addition of a minute trace of cobaltic oxide, the tints produced by ferric or ferrous oxides. The infusible substances introduced into mixtures in order to reduce shrinkage, being generally of a white colour, heighten the whiteness of the wares produced.

For all manipulative processes, it is necessary to reduce the raw materials to a fine state of subdivision, either by grinding, or by diffusion in water. Wares whose different ingredients have been reduced to different degrees of fineness, even though the difference be imperceptible, are rendered more solid, and are better fitted to resist the temperature of the kiln, as well as the changes of temperature to which they may be afterwards exposed. Wares are produced from suitable mixtures (1) in the state of dry or slightly moistened powder, (2) in a plastic condition, (3) in a liquid state. In all processes of manipulation, care must be taken that the body of the ware be homogeneous throughout. Inequality of pressure, by disturbing the homogeneity of the substance, is a fruitful source of disfigurement and fracture. Although no trace of irregularity may be apparent in the unburnt ware, it will, if present, be discovered by the ordeal of fire. After manipulation, wares are gradually dried, and solidified by exposure to heat in suitably-constructed kilns. Glazing and the different processes of decoration generally require one or more additional firings.

The average proportion of fusible to infusible ingredients in different wares is approximately illustrated in the following table of the results of analyses:—

	Hessian Crucible.	Stone-ware and Terra-cotta.	Earthenware.	English China.	Parian.	Porcelain.					
						Chinese White body.	Glaze of same.	Japanese Egg-shell.	Sèvres Body.	Sèvres Glaze.	Berlin.
Silica	71·00	74·00	71·00	38·88	54·80	75·0	67·5	78·8	58·0	74·3	71·3
Alumina	25·00	22·04	26·00	21·48	36·21	17·8	14·5	17·8	34·0	18·3	23·7
Ferric oxide ..	4·00	2·00				0·2	2·5	0·6			1·7
Calcic oxide ..		0·60		10·06		1·0	10 0	0·2	4·5	0·4	0·6
Magnesic oxide		0·17				0·5	1·0	trace	0·5	0·2	
Alkali: Sodic oxide ..			3·00		8·80	1·0	0·5	2·0			0·6
Alkali		1·06		2·14							
Alkali: Potassic oxide ..						4·5	4·0	0·2	3·0	6·5	2·0
Calcic phosphate				26·44							

Raw Materials.—The materials used in the manufacture of pottery may be divided into four classes:—(I) Plastic clays; (II) glass-forming materials, used either in the body or the glaze; (III) indifferent substances; (IV) colouring agents.

Class I.—Kaolin, Cornish or China clay (see p. 635); artificial Cornish clay of Belleek (see p. 639); Fire-clay (see p. 638).

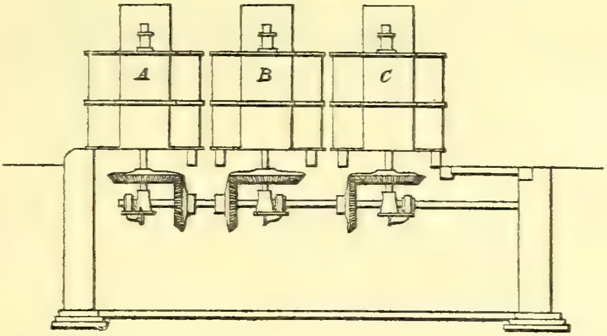
The "blue," "ball," or "pottery" clay of Dorsetshire and Devonshire is highly plastic. The upper beds of this clay frequently contain a large proportion of sand, and furnish a body which, without further admixture, is suited for the manufacture of ordinary stone-ware. The finest quality of the clay is found at a considerable depth; it is of a uniform blue-grey colour due to organic matter, is unctuous, and free from grit; it mixes with water with some difficulty; when treated with acids, no effervescence takes place; when subjected to a moderate heat, it becomes white, hard, and but slightly absorbent; with an intense heat, it is rendered so hard as to resist scratching with a steel point, assumes a yellow tint, and becomes non-absorbent. There is but a trifling proportion of iron intimately mixed with the clay, although nodules of pyrites are of common occurrence; the free silica present in the clay is in a state of exceedingly fine division.

TABLE OF RESULTS OF ANALYSES OF SAMPLES OF DIFFERENT CLAYS.

	Kaolin Cornish.	Kaolin S. Yrieix.	Stourbridge Fire-clay.	Dorsetshire Clay.	Devonshire Clay.
Silica	46·32	48·37	64·10	48·99	52·06
Alumina	39·74	34.95	23·15	32·11	29·38
Iron	0·27	1·26	1·85	2·34	2·37
Calcic oxide	0·36	..	..	0·43	0·43
Magnesic oxide	0·44	trace	0·95	0·22	0·02
Sodic and potassic oxides	12·67	2·40	..	3·31	2·29
Water		12·62	10·00	11·96	12·83

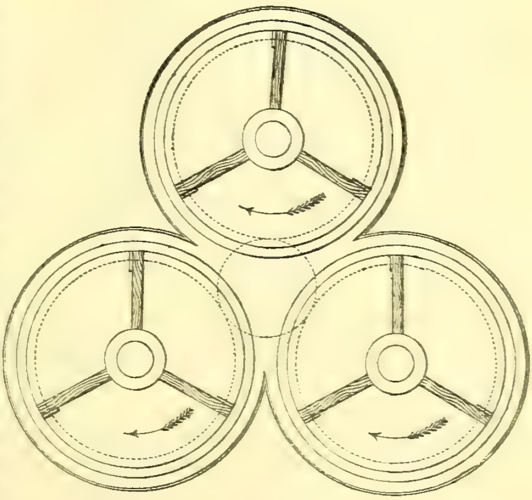
Preparation of Clays.—All clays, after extraction, are heaped up in the open, and exposed to the weather for as long a period as possible. Lengthened exposure tends to disintegrate the mass of the clay, and it is certain that ware containing clay which has been long exposed, is less liable to shrinkage than if the clay has been mixed with the other ingredients of the ware without previous exposure. In China and in France, it is customary to preserve the prepared mixtures for a long period; whereas in England, directly the clay has been incorporated with the other necessary substances, the mixture is considered ready for use. Fire-clay and the dry sandy clay derived from the upper strata of the blue-clay deposits, are prepared for use by grinding; kaolin and superior blue clay, by diffusion in water. The mills employed for grinding dry clays resemble ordinary mortar-mills. Diffusion is effected by stirring the masses of clay in tanks of water, by means of paddles worked by hand or machinery. The process of mixing the clay and water is known as "blunging," and the machines in which the process takes place, as "blungers." The simplest form of machine-blunger is a horizontal wheel, with paddles attached to the circumference, revolving in a round or octagonal pan.

1105.



Power is communicated to the shaft of the wheel from beneath by suitable gearing. Fig. 1105 represents three blungers A B C, intended respectively for ball-clay, kaolin, and "shavings" of unburnt ware (which represent the plastic constituents of earthenware), driven as described. Agitation may be increased by fixing projecting perforated arms to the inside wall of the pan, against and through which the clay is driven by the revolution of the paddles. The most recent form of blunger consists of an octagonal cast-iron pan,—the octagonal form aiding the process of disintegration,—with a circular casting to ward off the material from the bearings of a central spindle. To the spindle, are fixed six oblique blades, arranged in accordance with the principle of an archimedean screw. When water and clay have been introduced, and the spindle has been set in motion, the clay is gradually raised to the level of the topmost blade, where it is dashed against splash-boards, and thrown to the bottom of the pan, to be once more raised and rejected, until such time as the mixture is complete. Fig. 1106 is a view of three communicating

1106.

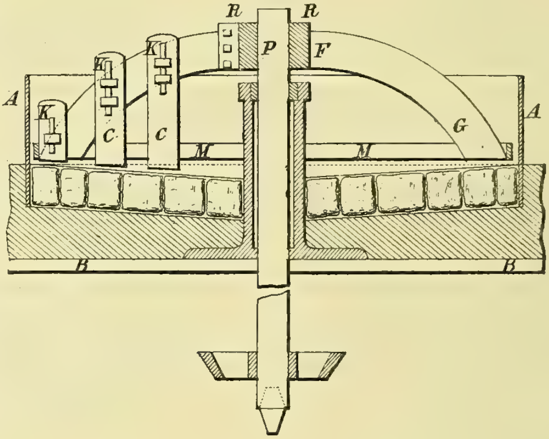


blungers driven from the centre. The pans are so arranged that the mixture is forced to pass successively from one to the other, by which means, friction and agitation of the mixture are increased.

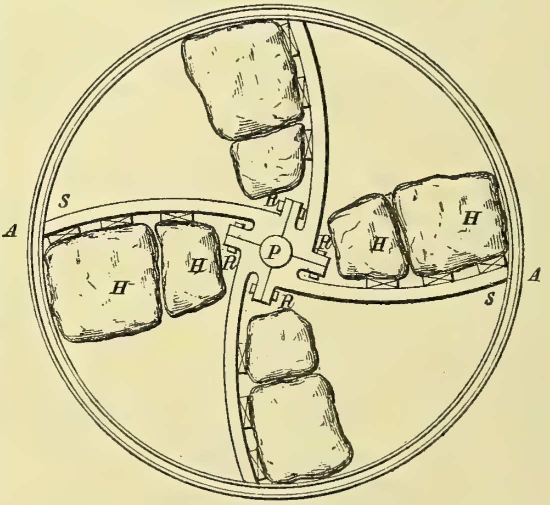
Class II. Glass-forming Materials.—Felspar, which may be regarded as a natural type of a glass (the potassium felspar being represented approximately by the formula K_2O, Al_2O_3, $6\,SiO_2$), is used both as a glaze and as a glass-forming ingredient in the body of porcelain. It is generally obtained from Sweden, in masses of a salmon-red colour. It becomes white when calcined.

Cornish stone is used for almost all English wares, both in the body and the glaze; it is a granite, in which the constituent felspar has been partially decomposed, but which retains sufficient alkaline silicate to render the mass fusible. It is quarried at St. Stephen's, in Cornwall, whence some of the best English kaolin is also derived. Pegmatite is a form of the same rock, but in a more advanced stage of disintegration; whereas granite consists of intermixed crystals of quartz, mica, and felspar, pegmatite retains no mica, and but a trifling proportion of quartz. Felspar, Cornish stone, and pegmatite are exceedingly hard, and are ground and diffused in water by mills of peculiar construction, illustrated in Figs. 1107–8. Fig. 1107 is a vertical, and Fig. 1108 a horizontal section of the mill; the external wrought-iron case or pan A is protected from injury from the grinding stones by an internal ring; B is the floor-level, and P is the shaft driven from below. The base of the pan is paved with blocks of chert, and the pavement slopes from the circumference towards the central shaft. To the shaft, are bolted, by the bolts R, the curved arms S. The shape of the arms F G is shown in Fig. 1107; to these, and to a connecting-bar M, the boards C are fastened, as shown at K. Blocks of chert H are chained to these boards, and are carried round by the arms. When the substance to be ground and the water have been introduced into the pan, and motion has been communicated to the shaft, grinding takes place between the contiguous surfaces of the blocks and the pavement.

1107.



1108.

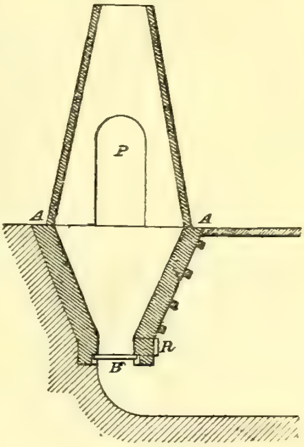


To the glass-forming ingredients already mentioned, must be added the carbonate and oxide of lead, sand, borax, and the carbonates of sodium and potassium.

Class III. Indifferent Substances which do not contribute Plasticity or Translucency.—Flint are obtained from the upper strata of the chalk. Those nodules are preferred which are black, compact, and free from iron and incrustation. When exposed to an intense heat, flint burns to a pure white. The whiteness and stability of the calcined flint are availed of for neutralizing the colour and contraction inherent to clay. Calcination is effected in a kiln similar to that represented in section in Fig. 1109: A is the ground level, with the chimney or cone rising from it; P, the charging-door; B, the grate for supporting the layers of coal and flint introduced through the door P; R, the stoke-hole. The calcined flints are removed by withdrawing the bars of the grate B.

The masses of calcined flint are reduced to powder in a "stamping-mill" or a "crusher." The former consists of a row of vertical, heavily-weighted, iron clubs or stamps, with projections on their upper extremities. These projections are successively caught and released by cogs fixed at intervals upon the surface of a horizontally-revolving cylinder; each stamp is raised and allowed to fall as its projection is caught by or released from a cog, and the flint introduced beneath is gradually pulverized by its descent. The crusher shown in section in Fig. 1110 grinds successive charges of flint between its iron jaws H J. The jaws are opened and shut by mechanism represented in the figure. The flint, reduced to a coarse powder, requires to be reground and mixed with water in a mill with stone runners, whence the mixture issues as a pure white creamy liquid.

1109.



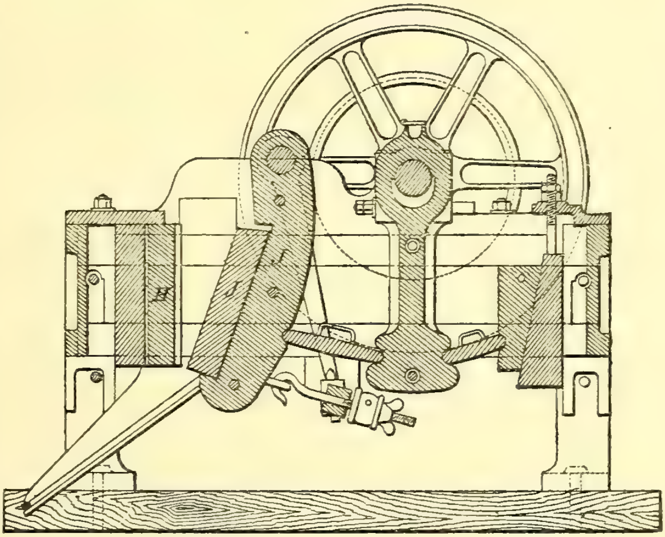
Bone-ash (calcic phosphate) is obtained by the calcination of bones, those being preferred which contain the smallest proportion of oxide of iron. The bones are generally freed from grease by boiling (see p. 1449), and calcined in the same manner as flint. In some cases, however, the grease is allowed to remain in the bones, and to act as an auxiliary fuel. Calcination is considered complete when the bones are perfectly white, and adhere to the tongue. They are crushed and ground with water. Bone-ash is the characteristic ingredient of English china.

Graphite is used in combination with fire-clay, for the manufacture of crucibles, and other apparatus employed in metallurgical operations (see Graphite, pp. 1087–93).

Class IV. Colouring Agents.—These are exclusively metallic oxides and metals (see under Decorative Processes, p. 1597).

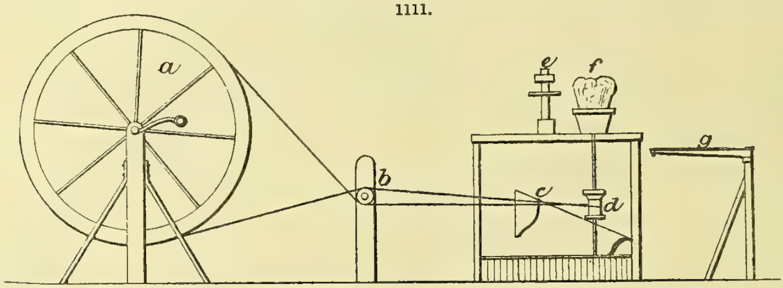
THROWING-WHEELS AND LATHES.—The essential part of a throwing-wheel is a horizontal disc, rigidly fixed to a vertical spindle. Rotary motion may be communicated to the spindle in a variety of ways. Fig. 1111 represents probably the oldest form of throwing-wheel not turned actually by the thrower's hand. The large wheel *a* is turned by an assistant, and communicates a vertical motion to the driving-band *b*. By turning the band, vertical motion is converted into horizontal motion for driving the pulley *d* rigidly attached to the lower part of the spindle. A pedal *c* is shown, which is under the control of the thrower's foot, and which impends over the driving-band. The pulley is conical, and by depressing the pedal, and consequently the band, the thrower can, to a certain extent, regulate the speed of the spindle, and can stop it altogether by throwing the band off the pulley. The speed, however, is mainly regulated by signs and words addressed by the thrower to his assistant. Fig. 1112 shows a wheel which is turned by the pressure of the thrower's foot upon a large horizontal wheel, rigidly attached to the lower part of the spindle.

1110.



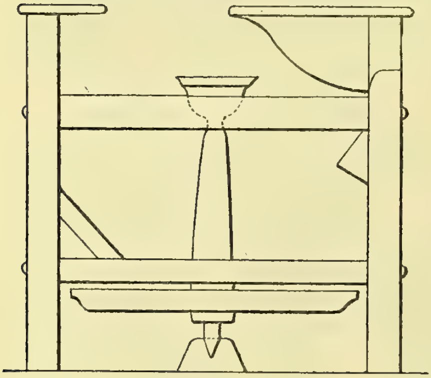
Figs. 1113, 1114 show respectively a throwing-wheel, and a moulding-wheel or jigger-head, both driven by steam power, and in both of which the speed is regulated on the same principle. In Fig. 1113, motion is communicated to the pulley G by a band running upon an overhead drum, which is driven by a steam-engine placed in any convenient position; G revolves in a perpendicular plane, and communicates similar motion to the large solid wheel D through the axle E; H is a friction-wheel, which is in contact with the wheel D, and rigidly attached to the spindle B, which turns the disc C. H can be vertically raised or lowered over the face of the wheel D, by the rod R, turning on the axis L, and counterpoised by the weight S. The thrower sits on the frame A; the motion of the wheel D in contact with the friction-wheel H causes the spindle and disc to revolve.

1111.



By depressing the weight S, the friction-wheel can be raised into a position opposite to the centre of the wheel D, and inasmuch as the speed in the centre of a wheel is less than at its circumference, the speed of the disc may be reduced. In the same manner, by raising the weight, the speed of the disc can be increased. In Fig. 1114, C is the jigger-head, and M is a stirrup, into which the operator can insert his foot, and depress or raise the rod R. The other letters represent the same parts as in Fig. 1113. In Fig. 1115, a throwing-wheel is shown without any seat for the thrower; but his position is such that he can place one foot on the treadle A, which gives an oscillating motion to the cone B, which is driven by a pulley rigidly attached to its shaft, as shown. When B, which is revolving, is shifted from its vertical position, it comes into contact with the cone C, which is fixed to the spindle of the throwing-wheel. The friction of the cone B against the cone C, causes the latter to revolve. The cone B is always at the same speed, but the speed of the cone C, and consequently of the spindle and disc, can be varied at the thrower's pleasure. If the displacement of the cone B be so slight that only its small end comes into contact with the big end of C, the motion of the spindle will be slow; but if the displacement be increased so that the large end of B comes into contact with the small end of C, the velocity of the spindle will be greatly increased.

1112.



1113.

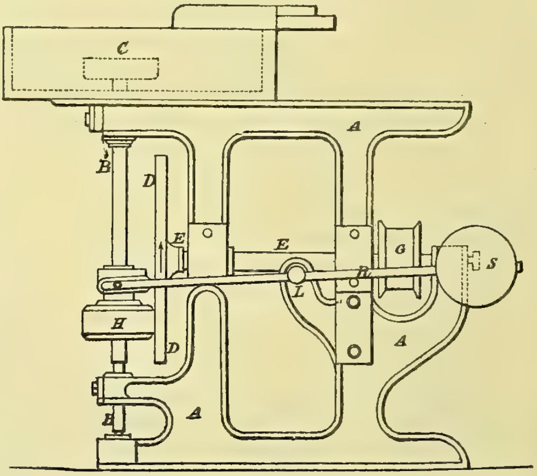
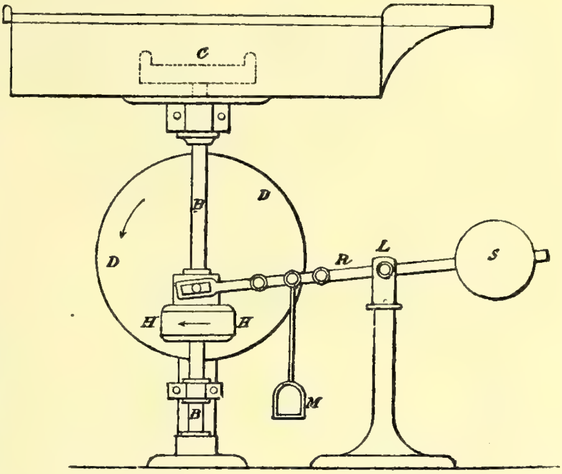


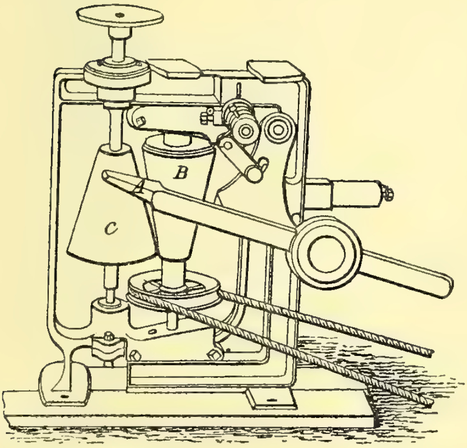
Fig. 1116 represents a lathe, whose speed is regulated upon the same principle as that just described. On the lathe-spindle, are fixed two cones, and running loose on a shaft parallel to it, are two other cones, revolving in opposite directions, and driven by pulleys. When the shaft is exactly parallel to the lathe-spindle, the two sets of cones are distinct, and no motion is communicated; but when the shaft, together with the loose cones, is turned at a slight angle to the lathe-spindle, which is accomplished by means of an arrangement of levers under the control of the turner's foot, either cone can be brought into contact, and the speed be varied at will. The old system of applying motion to the turner's lathe, and one which unfortunately is still in vogue, is by means of a large treadle worked by an assistant, who is usually a young woman. In modern potteries, the wheels, lathes, and jiggers are, as far as possible, so arranged that they can all be driven by one endless band, passing round the whole building in which they are placed, and driven by steam power. The band may be either above or below the floor.

Kilns or Ovens, and Muffles.—The two important processes for which ovens are required are (1) the hardening of ware, and (2) the fixing of glaze upon its surface. Wares, after manipulation, and a preparatory course of drying, are inserted in deep fire-clay trays ("saggers"), which are piled up in columns on the floor of the oven. After exposure to the heat of the oven, the ware is found to be hard, but, at the same time, porous in greater or less degree, and possessing a surface which is rough and usually absorbent. An absorptive or rough surface is well suited to receive certain forms of decoration, and especially the glaze which is applied in a liquid state. The arrangement of an oven for firing the glaze is similar to that used for hardening the ware, and differs only in size, the hardening-oven being considerably larger. The latter is technically termed the "biscuit-oven," and the ware after burning is said to be "biscuit-ware;" whereas the oven for firing the glaze is generally called the "glost-oven." In the glost-oven, the interstices between the saggers are luted with plastic clay. The old-fashioned biscuit- or glost-oven consists mainly of a dome, situated within a large conical chimney or "hovel." Round the base of the dome, or oven proper, project 8–12 fire-places, with ash-pits sunk below the level of the ground-line. The fire-places are charged from above, and the openings for charging can be closed at will. The flame and heat from each fire-place enter the oven by two flues, the one vertical, the other horizontal; dampers inserted in the outside walls of the vertical flues regulate the introduction of air. The horizontal flues pass under the floor of the oven, and converge to a vertical common central flue, by which the heat enters the oven. The smoke and products of combustion pass through openings in the upper part of the dome, into the chimney or hovel which surrounds it. In Robey's oven, the flame and heat enter by horizontal flues converging to a central opening in the floor, but the dome being closed during the process of firing, they are reflected back upon the saggers, and the products of combustion pass away by apertures

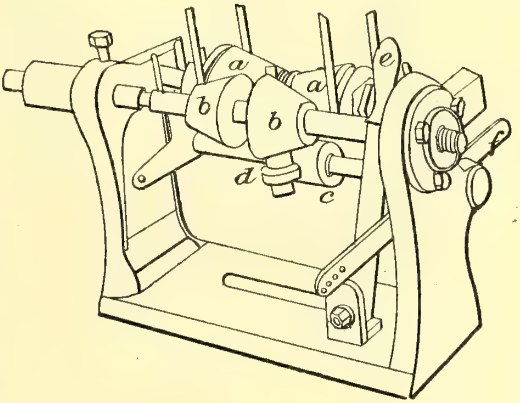
1114.



1115.



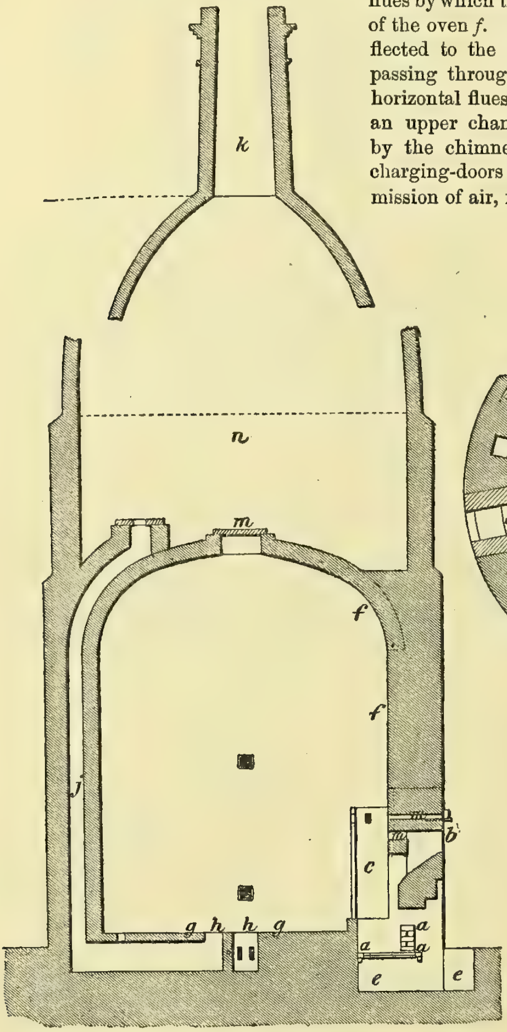
1116.



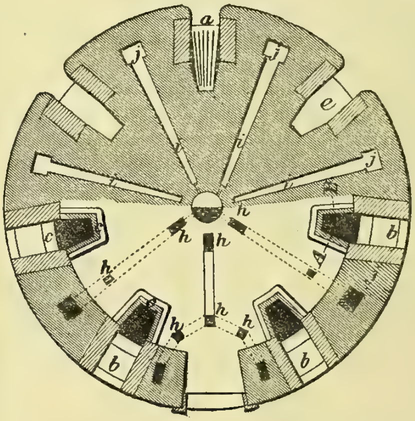
in the floor between the central opening and the wall of the oven, these apertures communicating with a circular flue, which discharges itself into an external chimney-shaft.

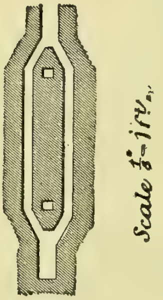
Figs. 1117 to 1119 illustrate the construction of Minton's patent oven. The figures represent respectively a vertical section of the oven, a horizontal section through the fire-places and the underground horizontal flues, and a section of an upright flue where it meets the trial-holes. The grate-bars *a* have temporary brick partitions to prevent the fuel falling into the ash-pit *e*; *b* are the doors by which the fuel is introduced; *c*, the fire-places and vertical flues by which the flame is directed towards the upper part of the oven *f*. The vent *m* being closed, the heat is reflected to the floor *g*, and the products of combustion, passing through several openings in the floor *h*, into the horizontal flues *i*, escape through the vertical flues *j*, into an upper chamber *n*, and thence into the atmosphere by the chimney *k*. The small openings *m* above the charging-doors act as dampers for regulating the admission of air, necessary to ensure complete combustion. The upper vent *m*, as well as the flue communicating with central vent *h*, is opened when the firing has been completed, to assist in cooling the ware. The upper chamber helps to equalize the draughts of the different fire-places. The advantages claimed for this oven are (1) saving of space by doing away with the external hovel, as well as the projecting fire-places, (2) saving of fuel, (3) complete combustion of the fuel, and consequent prevention of nuisance.

1117.



1118.

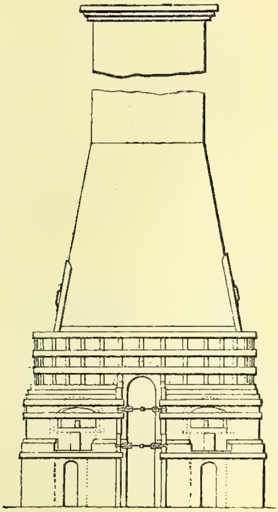




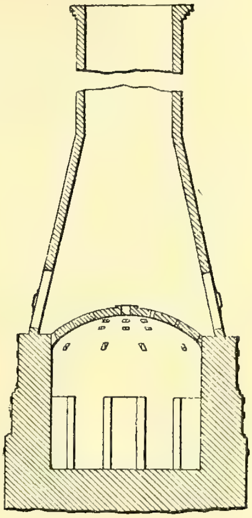
1119.

For ware which is hardened and glazed in one firing, the glaze being produced by the combination of volatilized salt with the material of the surface of the ware, ovens are constructed with ports which can be opened or closed at will, or the openings in the crown of the oven are utilized as well as the fire-places for the introduction of the salt. Wares glazed by this process are exposed without saggers to the full heat and flame of the fires. Coal with a small proportion of coke is used as fuel. Figs. 1120 to 1123 represent respectively the exterior, vertical section, and horizontal sections through the fire-places, and through the crown of the oven, showing the apertures or ports, of an ordinary up-draught salt-glaze oven. In Figs. 1124 to 1126, arrangements are shown by which an up-draught oven may be converted into a down-draught oven. The burning-chamber *a* is enclosed at the top by the arch *b*, the apertures in which have been closed by tiles, but may be opened for the introduction of salt; *c* are the fire-places, the flame entering the oven indirectly through the small apertures in the vertical flues *c*. Fire-clay blocks, placed on end on the floor of the oven to support the ware, are so arranged as to leave intervals for the escape of the reflected gases into the underground horizontal flues *f*, whence they escape through the two horizontal flues *g* into the flue *i*, which enters the chimney above a valve *e*, so as to allow the space D to be used for a drying-room or for burning terra-cotta.

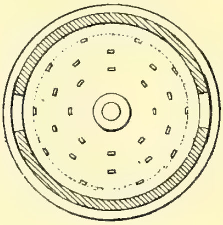
1120.

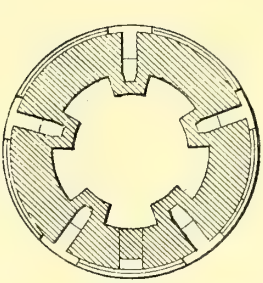


1121.



1122.

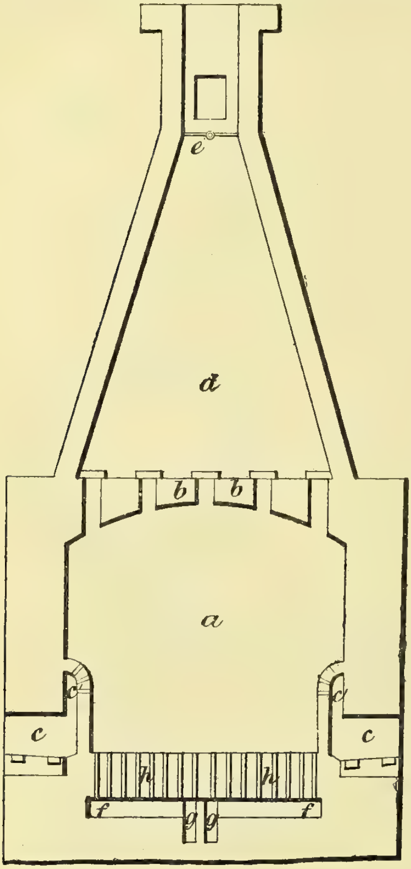




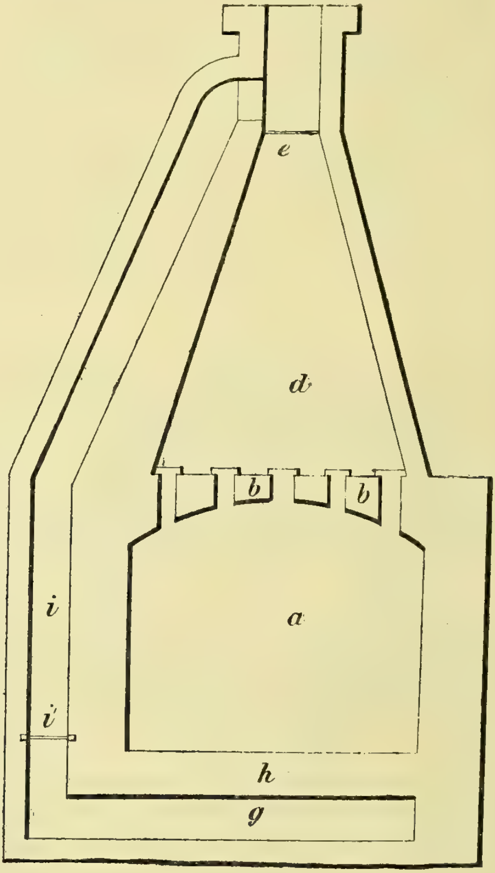
1123.

Figs. 1127, 1128, and 1129 illustrate the application of the principle of Siemens' gas-furnaces to the burning of pottery. Fig. 1127 shows a longitudinal section through four connected ovens; Fig. 1128, a sectional plan of the same; and Fig. 1129, a transverse section of the fourth oven. The objects represented in the ovens are bricks, but pottery can be burnt with equal facility. The four ovens A^1 A^2 A^3 A^4 are connected with the gas-generator, the air, and the chimney, in the following manner. The bottom of A^1 communicates with the top of A^2 through the passage a^1; the bottom of A^2 with the top of A^3 by a^2; the bottom of A^3 with the top of A^4 through the passage a^3; and the bottom of A^4 with top of A^1 by passages *x* and a^4. Slides c^1–c^4 for dampers are provided in each of the passages a^1–a^4, but there is only one damper for all the four passages, and it is consecutively placed in each. An underground flue B^4 (Fig. 1129) passes from the gas-generator along the front of all four ovens, before each of which it opens into the vertical shafts D^1–D^4, which are closed at the top, and from which, branch the pipes E^1–E^4. These pipes enter the centre of the side of each oven, and branches e^1–e^4 on the same also enter into the passages already mentioned. All these branches are provided with valves, actuated by the levers b^1–b^4, by means of which, the gas can either be admitted through the passages a^1–a^4 into the top of the oven, or through the branches E^1–E^4 into the middle of the ovens, or the gas can be shut off altogether. When the ovens are filled with ware to be burnt, tubes F^1–F^4, with perforations, are placed in them, in such a position that the gas, when entering the ovens through the pipes E^1–E^4, passes into these tubes, and is thus more equally distributed. Each of the ovens is also provided with an aperture G^1–G^4 at the bottom, connecting it, by means of a branch, with the flue H conducting to the chimney-shaft; each of the openings can be closed by dampers g^1–g^4. A large opening I^1–I^4 is provided at the top of each oven, for the purpose of filling and emptying it; each of these is temporarily bricked up when the oven is at work, but the one being open where the oven is being charged, admits air to assist combustion of gas in the oven that is being fired. If ware in A^1 is being fired, and A^2 has been recently filled, and is being heated preparatory to firing, and A^3 is being emptied and filled afresh, and A^4 has been fired and is cooling, then the action throughout is as follows. All the passages from the gas-generator to the ovens are closed, except e^1; the damper will be placed in passage a^2, and all communications with the flue H leading to the chimney will be closed except G^2; gas enters at the top of A^1 through a^4; at the same time air enters through the open oven A^3, passes through A^4, and becomes considerably heated; then passing through the passage X to the oven A^1, it mixes with the gas, and causes combustion. The products of combustion pass through a^1 to the top of oven A^2, thence through opening G into flue H conducting to the chimney. Each oven is charged, fired, and cooled in rotation. To facilitate the circulation of the heat, the wares or saggers are placed upon fire-clay blocks *f*, separated by suitable spaces.

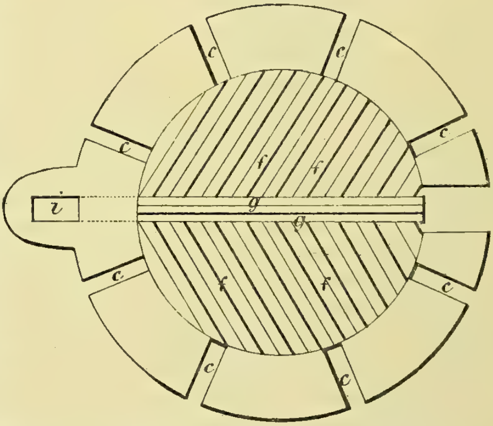
1124.



1125.

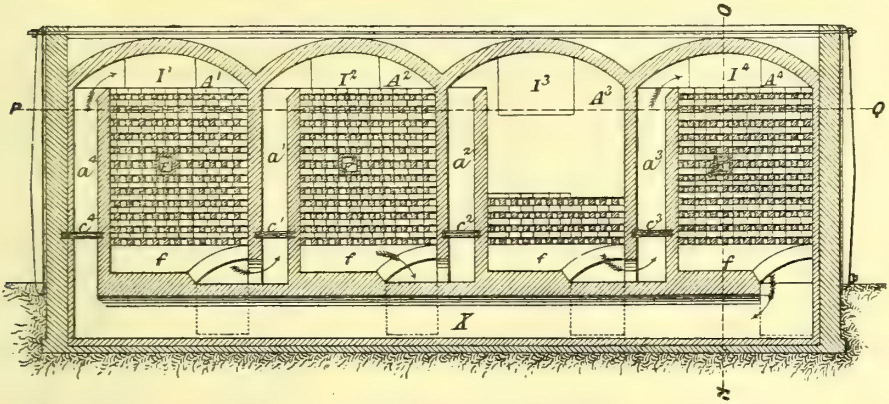


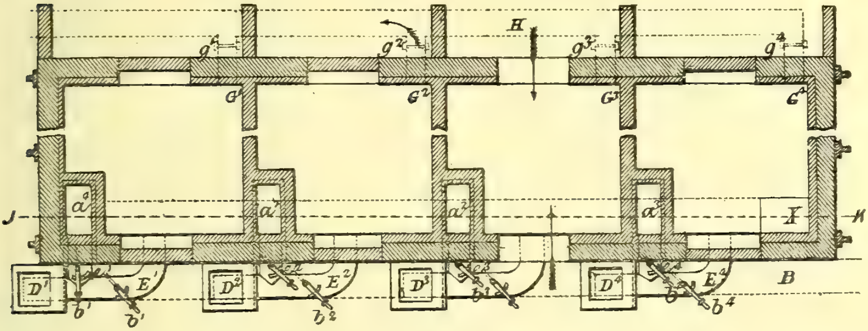
1126.



Continuous firing may be attained by causing the base of an oven to pass through fixed zones, in which the ware on the base of the oven is successively warmed, fired, and cooled. For this purpose, the oven is annular in form, and is heated by gas on the regenerative principle. Fig. 1130 is a vertical section, and Fig. 1131 a plan, of the annular oven. In Fig. 1130, T_2 is the annular floor or table, having a refractory facing, and being mounted on wheels *t*, which run on circular rails. On the under side of the table T, is a rack, gearing with a wheel on a shaft W, by turning which, the table is caused to revolve in the direction of the arrow (Fig. 1131). The wheels and axles of the table are protected from excessive heat by flanges attached to the sides of the table, and dipping into troughs of sand *s*. The annular chamber in which the table revolves is divided into four zones, namely, one for introducing or removing the ware, one for warming, one for burning, and one for cooling the ware before removal. The warming and cooling zones are interchangeable by means of two sets of apertures *p*, through either of which the gas and air can be

1127.

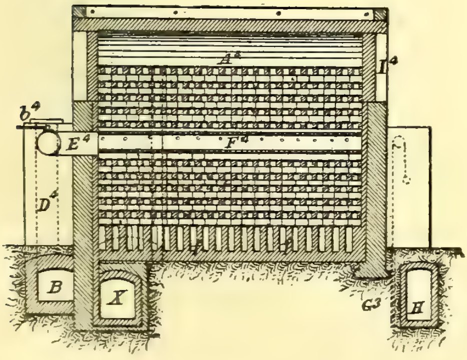




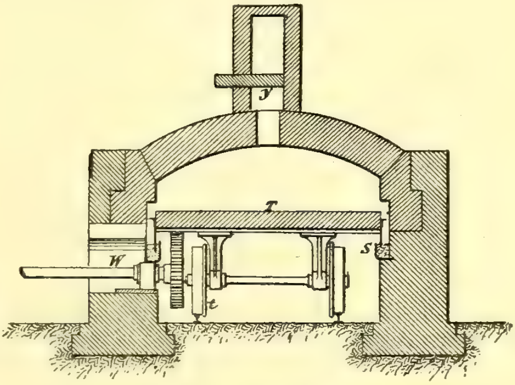
1128.

introduced at will. If the gas and air enter by the apertures on the right, the flame sweeps through the heating zone X, and the products of combustion escape through the apertures on the left, and heat the regenerator with which they are connected. When the left regenerator is heated, and the right regenerator connected with the apertures on the right is cooled, the gas is

1129.



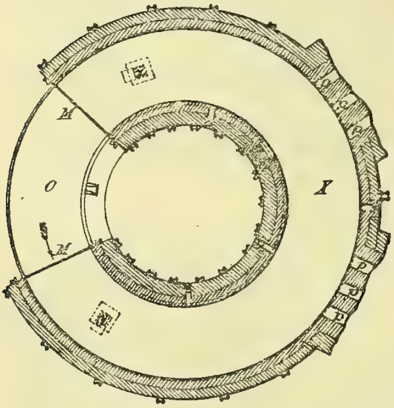
1130.



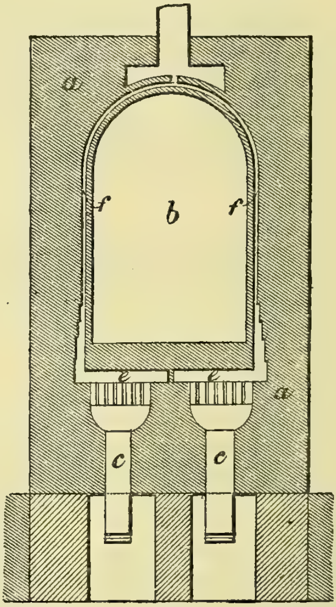
introduced by the apertures on the left, and the products of combustion pass into the right regenerator. Whilst the flame passes from right to left in the zone X, the adjacent zone is heated by opening the flue Z, and drawing part of the flame in that direction, the adjacent zone being in this way converted into a warming zone; whereas when the flame passes in an opposite direction, and the flue Y is opened, the zone about Y is converted into the warming zone, and the zone about Z into the cooling zone. The warming and cooling zones are separated from the cold zone O by means of sliding valves M. Ware to be burnt is placed upon the part of the table O, the valves M are raised, and the table conveys the ware away from O. As the table is caused gradually to revolve, fresh wares are introduced, and burnt wares are removed at O. At each movement of the table, both the valves M require to be raised.

Closed Kilns or Muffles.—Biscuit-ware is very commonly printed with a colour mixed with a medium of a dense oily nature. This oil must be removed from the ware before the liquid glaze can be evenly spread upon its surface. The removal is effected by placing the ware in a closed chamber or muffle, beneath and around which, heat is directed by flues suitably disposed. This process is known technically as "hardening on," and the kiln used for this purpose as a "hardening-on kiln." A smaller muffle and kiln constructed on the same principle is used for fixing enamel, painting, gilding, silvering, and other forms of applied decoration to the surface of a glazed ware. The wares in either case are placed in the muffles without saggers or other protection, the fronts of the muffles, which are removable, are replaced, and all openings are luted with fire-clay, except such as are necessary for observing the course of the fire.

1131.



1132.



The manager of the Royal Worcester China-works has patented an arrangement for heating a small muffle by means of the ordinary town gas supply. A series of tubes *c* (Fig. 1132) is connected with the main, and terminates in groups of burners; the heat from each group is received into a separate compartment *e*, formed under the bed of the muffle *b*, *a* being the outer wall of the kiln. The heat from the separate compartments *e* is conducted by separate flues, passing in various directions about the muffle, into a common chimney above.

Fig. 1133 shows two or more kilns containing muffles connected with a central chimney-stalk: A is a muffle built of overlapped tiles; B, the kiln in which the muffle rests, showing the ports for directing the flame and heat from the fire-place beneath to play upon various parts of the muffle; C D, auxiliary flues; E, the main flue passing into the central shaft H; F Y, dampers; I, the entrance to the shaft for the stokers, as the fire-places are charged from within the shaft.

Although it is impossible to divide pottery into accurately distinct species, it will be convenient to classify the different kinds of ware in the following manner:—

I. Wares rendered coherent by the removal of the water mechanically combined—Sun-baked wares.

II. Wares hardened and rendered anhydrous by artificial heat, but the porosity of which is unaffected, owing to the infusibility of the ingredients—Crucibles, Saggers.

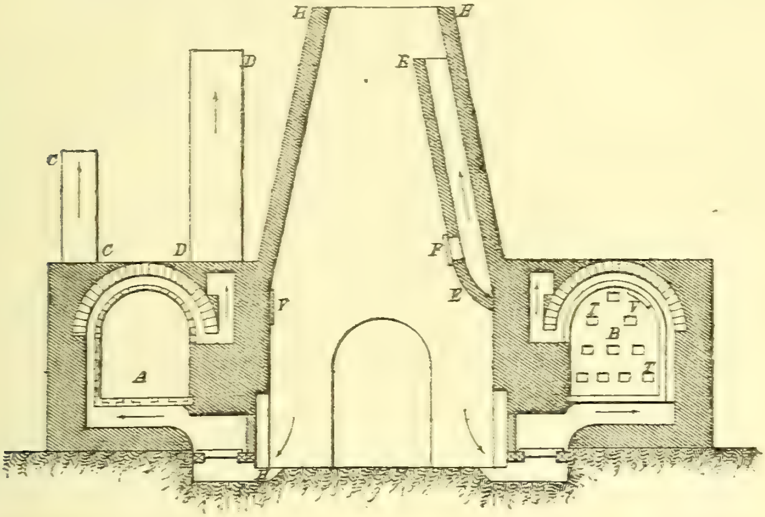
III. Wares fired at a comparatively low temperature, and porous in texture—Bricks, Majolica, Terra-cotta, Drain-pipes.

IV. Wares fired at a high temperature, and dense in texture, but perfectly opaque—Stone-ware, Earthenware.

V. Wares rendered translucent by the fusion of an incorporated felspathic glass—English china, Parian ware, true Porcelain.

Fire-ware.—In selecting clays for the manufacture of fire-ware, particular attention must be paid both to their chemical nature and to their physical aggregation. Fire-wares are required mainly for three purposes:—(1) To withstand great alternations of temperature, as in the cases of saggers; (2) to resist intense heat, without shrinkage or fusion, and, at the same time, to retain heat with as little loss as possible, as in the case of furnace-bricks; (3) to resist an intense external heat, accompanied by the internal corrosion of metals or other substances in a state of fusion, as in the case of crucibles. The refractoriness of a fire-clay may be estimated by the result of an analysis. If the proportion of foreign matter, that is to say of the alkaline, calcic, magnesic, and ferric oxides, exceed 4½ per cent., the clay is unsuitable for furnace-bricks or crucibles. No faith must be placed in the colour of a fire-clay, as the appearance of whiteness may be due to an excess of calcic oxide. The relative shrinkage of a sample of fire-clay, whether by withdrawal of moisture or by fusion, is a point demanding particular consideration in the selection of clay for the manufacture of furnace-bricks and crucibles; it is best determined by making a brick of the clay under examination, breaking it in half, and burning one half whilst retaining the other for comparison. If the burnt and unburnt halves fit together exactly, the sample may be pronounced satisfactory. The liability to corrosion is best determined by making small experimental crucibles of the clay, and fusing in them such substances as borax and plumbic oxide. If the corrosion in a given time be excessive, the clay must be condemned as unfit for metallurgical purposes. The importance of physical aggregation rests upon the fact that a coarse, porous, brittle ware withstands changes of temperature better than a dense one; whereas a smooth, dense ware is better fitted to withstand corrosion, and to retain heat. A clay is rendered naturally porous by the presence of an excess of sand; the same result, however, may be attained or increased artificially by coarse grinding, and by the addition of the coarse powder of burnt, broken, fire-clay ware, or of a foreign refractory or infusible substance, such as graphite.

1133.



Saggers.—Saggers are not required to withstand a very intense temperature for prolonged periods, nor the corrosive action of fused material; the economy, however, of a manufactory depends in some measure upon the possibility of using them several times, and upon their withstanding, without breaking, repeated heating, cooling, and reheating. As the saggers in a kiln are piled in columns, the result of the breakage of one sagger during firing may be disastrous. Considerable care is therefore expended upon the selection and preparation of fire-clays for sagger-making, but their purity is inferior to the fire-clay used for crucibles and fire-bricks. The mixture generally employed consists of inferior fire-clays, together with a proportion of the powder of broken burnt saggers.

The fire-clays, after arriving at the works, are exposed in heaps to "weather" for as long a time as possible (see Clay—Fire-clay, p. 639). When required for use, the clay and broken saggers are coarsely ground under iron wheels working upon an iron revolving base. The mixture is then thrown through a grating into a circular underground tank containing water, and is crushed and mixed with the water by the revolution of a horizontal-bladed wheel. When the liquid mixture has been tested, and found to be sufficiently dense, it is run through a long imperceptibly-sloping trough, in order that the coarser grit and particles of iron may be precipitated by gravitation, and be intercepted by depressions arranged in the trough at regular intervals. From the trough, the mixture passes into a steam-jacketed iron tank, in which it is reduced by evaporation to a suitable consistency for manipulation. The surplus heat from the tank is utilized in the drying-rooms.

The plastic clay is removed from the evaporating-tank, and, in order to ensure a close-grained and tenacious mass, is either repeatedly rolled and beaten by manual labour, or passed through a mill ("pug-mill"), in which it is mixed, pressed, and kneaded by the revolution of a cylinder armed with splayed knives, and from which it is finally driven in a continuous compact stream of the exact form of the orifice from which it issues. The stream of clay is cut into blocks, which are carried wherever they are needed for manipulation.

Saggers are manufactured in different ways, according to the different purposes for which they are intended. They may be moulded by hand on large potters' wheels, or whirling-tables, in the same manner as deep hollow ware is formed, or the bases and sides may be formed separately. The bases are formed by beating the plastic clay into iron rings of the same shape, but of larger circumference than that of the saggers of which they are to form part.

The sides of small saggers may be made from lengths cut from a cylinder issuing from the annular opening of an expressing-machine (compare Stone-ware), and may be cemented by liquid slip on to bases formed as described. The sides of large saggers are formed from strips of the clay mixture which have passed under a roller-press. The press consists of three parallel iron cylinders, supported so as to impend over a movable iron table. The blocks of clay are placed in shallow troughs of varying width, resting upon the iron table. The table can be moved backwards and forwards beneath the cylinders, and carries with it the troughs and their contents. The cylinders are caused to revolve by the resistance offered by the clay, which, at the same time, is evenly spread and compressed. The depth of the troughs forms a gauge for the thickness of the clay. The strips of compressed clay are now removed, and wound round wooden drums, which rest upon the sagger bases, but in such a manner as to leave a margin to which the sides can be attached. The side is attached to the base by kneading with liquid slip, and the edges are united in the same manner. The saggers thus formed are dried and baked.

Fire-bricks.—The consideration of the manufacture of fire-bricks and shaped blocks for the construction of furnaces hardly falls within the scope of this article. Suffice it to say, that the importance of non-liability to shrinkage in ware of this description rests upon the fact that the greater part, and especially the crowns and beds, of furnaces intended to resist intense and prolonged heat, are built of green or unbaked material. (See Glass, p. 1049 ; also Spons' Dictionary of Engineering, article Brick.)

Crucibles.—Crucibles are generally formed from a mixture of almost pure fire-clay (compare analyses, p. 1559), with a greater or less proportion of fire-clay specially burned for the purpose, or of the powder of ground broken crucibles. The burnt clay is always coarser than the raw, fire-clay. Crucibles, and especially large crucibles for melting glass, are built up layer by layer by hand (see Glass, p. 1046). Crucibles of various sizes are made on the wheel, and by machinery. Machinery is largely used at the works of the Battersea Plumbago Crucible Co. The processes there employed are as follow. A graphite is selected which is as free from foreign matter as possible. The fire-clay and graphite are dried and ground separately; they are then weighed and mixed in nearly equal proportions. The mixture, incorporated with a small quantity of water, is passed through a pug-mill, and the stream of compressed and plastic material, as it issues from the mill, is cut into blocks and stored for future use.

When required for use, it is again passed through the pug-mill, and the blocks are kneaded and weighed, preparatory to working up in the machine represented in Fig. 1134, which is used in the manufacture of open crucibles for metallurgical operations. A heap of prepared clay is weighed, and inserted in a plaster mould *o*, which rests in, and is caused to revolve by, an iron cup *p*, attached to a spindle, to which, motion is communicated from beneath. A gimlet-shaped tool *a*, fitted to a block *b*, can be depressed into the clay by means of a horizontal frame, balanced by weights K. The block *b*, together with the tool *a*, can be moved horizontally in the frames by means of a handle *g* and threaded rod. The frame can be maintained in any desired position by a catch *n*. When the frame is fixed, and the mould is caused to rotate, the tool *a*, by turning the handle *g*, is moved horizontally, and spreads the clay against the wall of the mould; by this means, the form of the interior of the vessel is given by the tool, whilst that of the exterior is produced by pressure against the internal surface of the mould. By varying the forms of the tool and mould, variously shaped vessels may be produced. When the vessel has been fashioned, and the motion checked, the tool is moved into the centre of the vessel by turning the handle *g*, the frame with the tool is raised, and the mould with the vessel inside it is removed to a drying-room by means of a suitably-constructed crane. The crucibles are burnt in saggers or muffles. In order to prevent absorption of moisture and dirt during storage, they are often coated with a waterproof paint, or with an enamel which is permanently fixed by firing.

Stone-ware.—There are two very distinct species of stone-ware, the type of the one being an ordinary glazed drain-pipe, whilst the type of the other is a vase of decorated Doulton ware. The materials and treatment of both are similar, although not identical; and both types may generally be seen in course of manufacture at the same works. Stone-ware is always dense, refractory, and opaque; the finer qualities resist corrosion by acids, and extreme changes of temperature, and, in some cases, are semi-vitreous, and capable of receiving coloured decoration. The basis of all stone-ware is the grey-coloured ball-clay from Dorsetshire and Devonshire, and especially those qualities containing a considerable proportion of sand. For common ware, a mixture is made of the ground ball-clay, with the powder of burnt broken goods; for fine and decorative purposes, a superior quality of the ball-clay is mixed with sand or flint and Cornish stone. The colour of the ordinary stone-ware, after burning, is buff passing into brown; whereas that of superior stone-ware is almost white. The majority of stone-ware is glazed by the indirect reaction of the vapour of sodic chloride with the constituents of the surface of the ware. The exceptions are Bristol ware, glazed with a mixture of felspar, borax, and plumbic oxide; certain common goods, which are glazed with mixtures of the oxides or sulphides of lead and iron, or with the oxide of manganese; wares glazed over by means of a "smear" (compare Decoration); and Wedgwood's jasper ware, which is vitreous, and possesses a naturally crystalline surface.

By the term "stoneware," salt-glazed ware is generally understood. Salt-glazed stone-ware is fired for biscuit, glaze, and decoration, when decoration is applied, at one time. All forms of decoration must be applied to the ware before burning (see Decoration).

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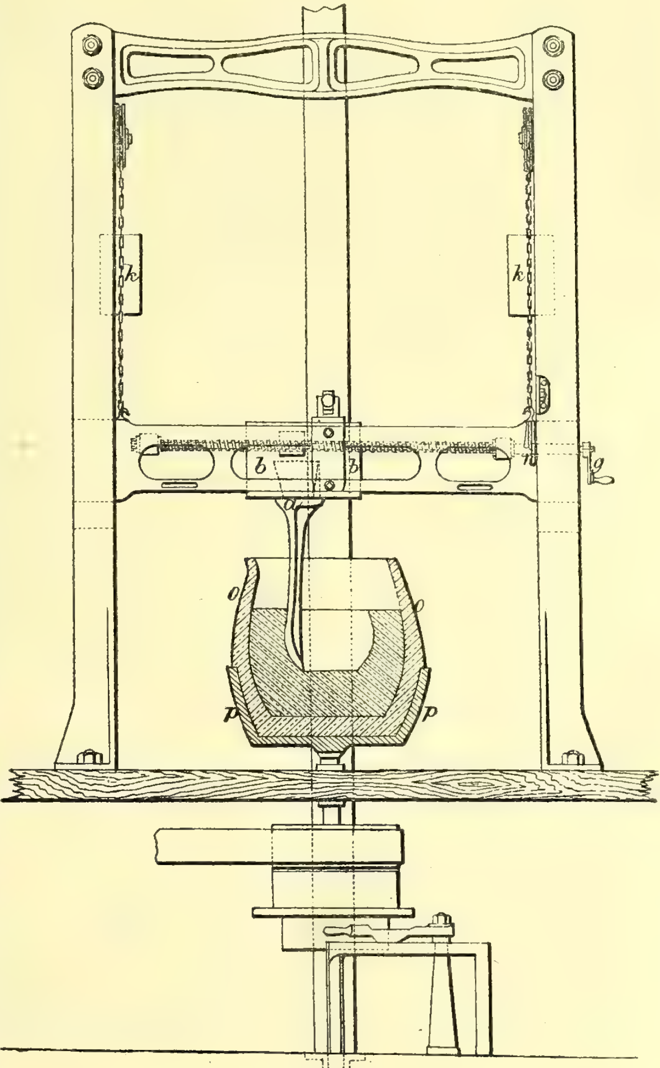

For a description of stone-ware kilns, see pp. 1565–6. The fuel generally used is coal, and the ware is exposed to the naked flame, without any protection. The difficulty of preparing colours for stone-ware decoration, which are stable enough to withstand this ordeal, can readily be understood. The heat of a stone-ware kiln is intense, and it is customary to burn terra-cotta, which is made from the same materials as stone-ware, on the roof or crown of the stone-ware kiln. Terra-cotta differs from stone-ware in its condition of solidification, which is less perfect, on account of the comparatively low temperature to which it is exposed. The unbaked stone-ware, preparatory to being exposed to the sodic chloride vapour in a salt-glaze kiln, is dipped in a mixture of sand and water. After the ware has been arranged, the fires are raised gradually. The salt (sodic chloride) is not introduced until 2½–4 days from first lighting, when the ware has nearly attained its highest temperature. Salt is thrown into the kiln with shovels at the fire-places, and through openings in the crown arranged for the purpose. The total charge of salt for an average-sized kiln is about 2 cwt. When half the charge has been thrown in, the fires are increased for a time, specimens of the ware are then examined, and if the inspection be satisfactory, the residue is added. The openings in the crown are now closed, and the ware is left to cool for 4–6 days. The injection of the salt causes dense white fumes of salt vapour tainted with hydrochloric acid to issue from the cone of the kiln. At Doulton's works, the fumes from all the kilns are gathered into and discharged from a chimney some 300 ft. high. By this means, all real nuisance is obviated.

The theory of salt-glazing rests upon the decomposition of salt vapour by water vapour. As the salt is volatilized, it unites with the water vapour arising from the combustion of the fuel, to form hydrochloric acid and sodic hydrate; the latter unites with the free silica in and on the surface of the ware, to form sodic silicate. The sodic silicate renders fusible a small proportion of the aluminic silicate of the body of the ware, and unites with it to produce a glass or glaze built up of the sodic and aluminic silicates. This glaze answers in composition to the glaze of Chinese and Sèvres porcelain; but it is more evenly spread, and, if possible, more thoroughly incorporated. If ferric oxide be present in the body of the ware, or if, as sometimes happens, red-lead be introduced into the kiln with the salt, ferric and plumbic silicates will respectively be formed, and will contribute to the fusibility of the glaze. A pure clay body is less readily glazed by the salt-glaze process than one containing free silica, alkalies, and ferric oxide; by the latter, if an appreciable quantity be present, the glaze will be tinted buff or brown. The scorched appearance, which may sometimes be observed on pieces of stone-ware, is due to the reaction of the salt vapour being in some way accidentally interrupted.

Manufacture of Common Stone-ware by "Expression."—Drain-pipes, roofing-tiles, perforated bricks, and similar articles, are produced by mechanical pressure. The processes are as follow. The ball-clay and burnt broken ware are separately ground under pairs of iron edge-runners. A scraper follows the runners, and drags the ground clay over an iron grating, through which the fine powder falls, the coarser particles being thrown back for regrinding. From the receptacle beneath the grating, the ground ball-clay is removed, and carried upwards in open pockets attached to an endless band moved by machinery. As the pockets turn to descend, the powder is thrown into a blunger, where it is incorporated with a small quantity of water, and a measured proportion of the ground burnt clay. The mixture is removed from the blunger, and supplied to a vertical pug-mill, by the knives of which, it is compressed, and forced downwards and outwards. The stream of prepared mixture is cut into blocks, and the blocks are carried by an endless band, fitted with shelves, to an upper floor, where they are stored for use. The expressing-machine occupies two floors, and the feeder is upon the upper floor, to which the blocks of clay are carried direct from the pug-mill. The principle of an expressing-machine in its simplest form is illustrated by Fig. 1135. The plunger and part of the cylinder in which it moves are represented. The clay can be introduced into the cylinder immediately below the plunger, and the door by which it is inserted can be securely closed; as the plunger, which moves airtight in the cylinder, is caused to descend, it compels the clay beneath it to assume the form of any resisting environment; and, if there be an opening, to assume its outline, and to stream through it so that a section of any part of the stream has the same outline as that of the aperture through which it has passed. If the aperture be a simple slit, the clay issues as a ribbon. Roofing-tiles are made by cutting into lengths a ribbon produced as described, placing the separate lengths whilst still plastic upon plaster moulds of the form which the tiles are required to possess, and baking them when dry. If the aperture be annular, the clay issues from it as a continuous hollow pipe. In order to form a perfect annular opening, it is necessary to support a core in the centre of the main opening, and in such a way that the supports shall not interfere with the continuity of the resultant pipe. The core *e* is attached to the base of the cylinder by the supports *a*. The cylinder is enlarged below the attachment of the supports, in

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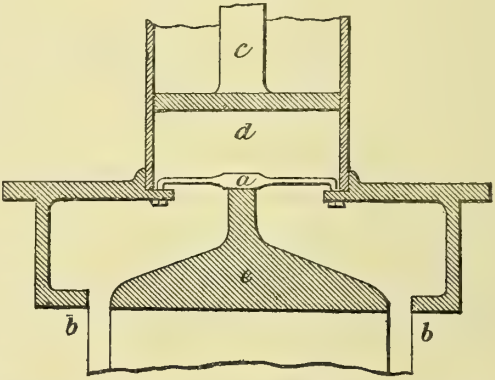

order to allow the reconsolidation of the clay after having been cut by the supports, and before issuing from the annular space *b*. As the pipe issues from *b*, it is cut by wire into any required lengths.

Additional apparatus is necessary to form pipes with flanges or sockets attached. A movable iron mould or core of the shape of the inside of the socket is placed by hand in contact with the base of the core *e*, so that the pipe, if the pressure be continuous, must be forced over it, and be enlarged in its passage. This internal mould is supported in position by a rim attached to the base of an iron collar, formed of two jointed halves. The internal form of the collar is the same as that which the exterior of the socket is intended to receive, and its internal surface forms a continuation of the outer edge of the annular aperture *b*. When the two halves of the collar are united, there remains no aperture for the escape of the clay, and it is therefore forced to adapt itself to the internal form of the socket-mould. Conical pin-holes are, however, provided in the collar, to permit the escape of imprisoned air, and the consequent perfect adaptation of the clay to the mould. The exudation of clay through these pin-holes marks the time when the socket has been formed, and when the collar and internal mould must be removed, in order to allow the simple pipe to follow after the socket. Wooden "forms" are used to rectify any inaccuracies in the shape of the sockets or barrels of the pipes. Expression may, in a similar manner, be applied to the production of a great variety of wares, as, for instance, in the manufacture of perforated and damp-course bricks.

Stone-ware jars, bottles, and jugs are fashioned on the wheel, which, in large manufactories, is generally driven by power. The more delicate specimens of decorative stone-ware, which are known as Lambeth ware, are formed on the hand-driven wheel. For the different decorative processes applied to stone-ware, see that section.

Tall chimney-pots are at times made up of as many as three lengths, fashioned separately on the wheel, and built up one upon the other. Y-shaped pipes are made by the union of two separately formed pipes. Siphon-pipes are made by moulding. Fig. 1136 represents the half of a plaster mould for this purpose: *a* are the studs or depressions by which the two halves of the mould are fastened together. "Bats" or thin sheets of clay are spread carefully by hand over the entire surface of the two half-moulds. The two parts of the mould are then united, and the division between the two halves of the pipe is carefully closed by the insertion of strips of plastic clay. Large filters are similarly fashioned; but in this case, external decoration is produced at the same time as the actual form of the ware.

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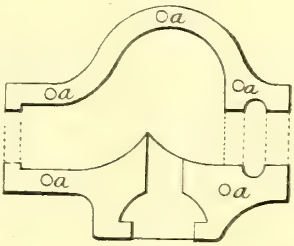

Earthen-ware.—Earthen-ware possesses a dense, opaque, and generally white body, with a rough fracture. The whiteness, opacity, and stability of earthen-ware are in a great measure due to the presence of a considerable proportion of calcined flint. There are many species of earthen-ware, distinguished by their fracture, or by the tints of their body or glaze. The ingredients of which earthen-ware is composed are ball-clay, kaolin, flint, and Cornish stone; and the glaze with which earthen-ware is generally coated is soft, containing plumbic oxide and borax. The blue or ball-clay and the kaolin or China clay, after their arrival at the works, are exposed to the action of the weather. It is convenient if the clay-banks can be so placed as to be above or on the same level with the sheds in which the clays are "blunged," that is broken up with water. When the clays are ripe, a certain quantity of each is moved to the blunging-shed, and subjected to the process of blunging. The clays are thrown into tanks containing pure water, and are mixed with the water, either by the mechanical action of blades attached to a horizontally-moving wheel driven by steam-power (see p. 1559), or by a laborious process of manual stirring with a wooden instrument resembling a large paddle. Separate tanks are provided for blunging the ball-clay, the kaolin, and scraps and shavings of broken unburnt ware. The density of the contents of each blunger is tested by weighing one pint of each in a standard pint measure. If the liquid in either case be too dense, more water is added; if not dense enough, the proportion of clay is increased. The weight of the standard mixture of ball-clay is 24 oz. a pint, that of kaolin being 26 oz. If the density be correct, each liquid mixture, or slip, is run separately by gravitation, the blungers being purposely erected on an elevation, either through a series of sieves, or into a horizontal, rotatory, cylindrical sifter. Figs. 1137, 1138 show an arrangement of sieves. Fig. 1137 is a vertical, and Fig. 1138 is a horizontal section of the apparatus. A series of sieves, with "lawns" of increasing fineness (two only are shown in the figure), are placed one above another, in such a way that the material can pass from one into the next. A backward and forward motion is communicated to each sieve by a hooked rod, loosely attached to a point on the circumference of a wheel which revolves in a vertical plane. The bases of the sieves rest upon narrow slabs of plate-glass, by which means, friction is reduced.

The actual form of the rotatory sifter is octagonal rather than cylindrical, and it receives a shaking motion in addition to rotation, through a strap driven by power. The sifting medium of the sieves and of the cylindrical sifting-machines is silk lawn, brass gauze having been tried without success. It is customary for potters to contract with the makers of the silk sifting-machines to keep their sieves in working order, as, owing to the great delicacy of the material, they are constantly liable to damage. The sediment retained by the sieves or sifting-cylinders is emptied from time to time into convenient receptacles, and returned to be reblunged. After sifting, the clay slips are run separately into the mixing-tank, in which, a measure fixed to one side indicates in inches the quantity of each material received, the density of each liquid having already been determined by weight. The relative quantities of the clays, as of the other substances, vary according to the nature of the ware it is intended to produce. The mixing-tank is generally of stone, measuring about 6 ft. sq. The flints, after calcination and crushing (see p. 1561), and the Cornish stone, after crushing, are ground separately with water. In the mills used for this purpose, the necessary friction is obtained between two surfaces of differently-grained chert. A cast-iron bed is evenly paved with blocks of carefully selected stone, but in such a manner that the circumference of the bed shall be at a higher level than the centre; the bed is surrounded by sides of wrought-iron, and the centre is pierced by an opening, in which, revolves an iron vertical shaft, driven by gearing from below. To the shaft, are attached four curved projecting arms, each provided with vertical, wooden, iron-tipped bars, which reach almost to the bottom of the pan, and propel heavy masses or "runners" of the chert rock.

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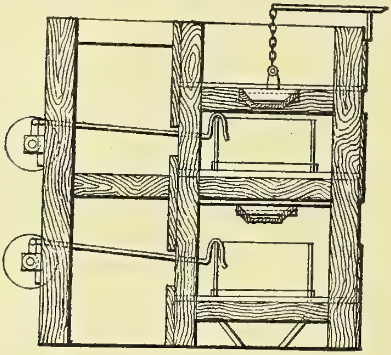

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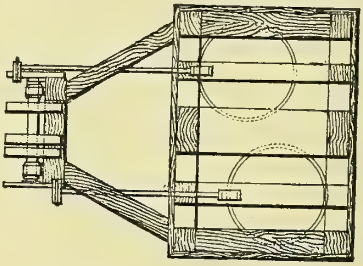

Pure water is first run into the pans formed by the beds and sides of the mills, and the materials to be ground are then added. As the "runners" are forced round and round, the flint or Cornish stone is respectively ground to an impalpable powder, and worked with the water so as to form a compound of a thick creamy consistency. The mixture in either case is allowed to settle for a short time, and is then drawn off through plugs at different heights in the sides of the pans. From the top plug, water is drawn off; from the second, the slip or mixture which is to be used; and from the bottom plug, a sediment which requires to be reground. The flint and Cornish stone slips are thence conducted into circular tanks, where water is gradually added, and where the material is mixed with the water by the revolution of an agitator or spindle with arms and paddles, until such time as the mixtures respectively attain a standard density. The density is determined, as in the case of the clays, by weighing a fixed quantity. The standard weight of a pint of flint slip is 32 oz., and that of Cornish stone is generally the same. The creamy liquids are run through pipes into store-tanks in the clay blunging-shed, the inlet to the pipes being slightly above the level of the bottom of the agitating-tanks, in order that any coarse sediment still present may be retained for regrinding. The flint and Cornish stone slips are now under the same roof with the clay-blungers and mixing-tank, and are introduced into the mixing-tank, the quantity of each being regulated by the measure attached to the side of the tank. At this point, also, any colouring mixture that may be required is introduced. In the mixing-tank, the clay slips, together with the flint, Cornish stone, and any colour that may be present, are thoroughly mixed by agitation, either by hand or by power. The mixture is then passed through three sifting-machines or three sets of sieves, each sifting-machine or set of sieves being covered with lawn of increasing fineness. The coarsest lawn contains 50 threads in an in.; the finest, 120 threads. After mechanical sifting, the mixture is subjected to magnetic or electrical sifting, in order that it may be purified from minute particles of iron. For this purpose, the trough through which the fluid is conducted is furnished with a series of horse-shoe or electro-magnets, and the fluid passes through their field of action. After this double process of purification, the liquid mixture or slip reaches an underground store-tank or "ark," whence it is raised by pumps to be partially solidified by pressure and filtration.

The following table shows the number of inches of each liquid material of standard density required to make up 100 in. of the different earthen-ware mixtures in a liquid condition.

Ingredients.	Weight per Pint.	Earthen-ware proper.					Cream Colour.		Granite.	Iron-stone.
		A	B	C	D	E				
	oz.									
Ball-clay ..	24	32	35	36	40	25	48	65	10	24
Shavings and waste of unburnt ware ..	..	..	..	..	..	25	..	..	..	..
Kaolin	26	36	45	32	32	25	24	17½	40	24
Flint	32	22	15	20	20	12½	16	13¾	28	16
Cornish stone	31½–32	10	5	12	8	12½	12	3¾	22	36
		100	100	100	100	100	100	100	100	100

Fritt for Glaze of D.		Glaze for D.	
Ingredients.		Ingredients.	
Borax	30	Fritt	50
Kaolin	5	Cornish stone ..	25
Calcic carbonate	20	Plumbic carbonate	25
Cornish stone ..	30		100
Flint	15	or equivalent of oxide.	
	100		

The table serves rather as an illustration of the attributes of the different materials than as a basis for manufacture. Ball-clay (see p. 1558) supplies plasticity, but acquires a slightly yellow tint when fired, which is especially noticeable when the commonest qualities of the clay are used. Kaolin contributes plasticity, whiteness, and infusibility; flint contributes whiteness, stability, and an earthy fracture; and Cornish stone acts as a flux, and produces vitreosity. Whenever any one of these ingredients is in excess, the quality or qualities which it possesses show themselves in the resultant ware. Thus the mixture B will produce as white but a less vitreous ware than A, for although the proportion of ball-clay in the former is greater than in the latter, the proportion of the whitening ingredients, kaolin and flint, in B is greater than that possessed by A. In E, the proportions of ball-clay, kaolin, and flint are reduced, as deficiency in whiteness and plasticity is supplied by the addition of 25 per cent. of the shavings and waste of unburnt ware. The colour of the cream-colour ware is due to large proportion of ball-clay, which, in the samples given, amounts to as much as 48 and 65 per cent. "Granite" is vitreous, owing to a large proportion of Cornish stone; but part of this effect is balanced by the presence of an excess of kaolin, which renders the ware white, and somewhat refractory. "Iron-stone" is vitreous, owing to a comparative deficiency of clay, and a great excess of Cornish stone.

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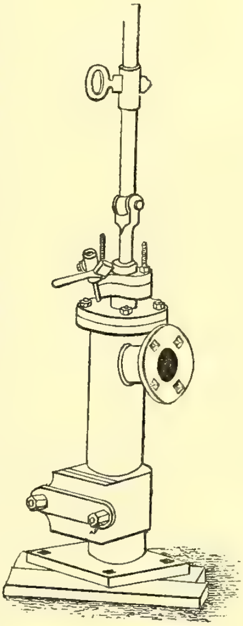

Fig. 1139 represents an ordinary pump used for raising the liquid clay mixture from lower to higher levels, whilst it is undergoing the different processes of refinement. The pump employed for forcing the slip from the store-tank into the press is of special construction, and of considerably greater power. The press is made up of a series of large, oblong, wooden, shallow trays or frames, usually 24 in number, which are grooved or ribbed on both faces, and, when placed vertically side by side, leave intermediate spaces of about ⅜ in. In each of these spaces, is laid a piece of strong calico, of rather more than double the size of one of the frames; and the calico is so folded as to form, in the space between the frames, a bag, into the upper side of which, a small brass pipe is fixed, which can be adjusted to a main supply-pipe running above the frames and connected with the slip-pump. When the frames, with the bags between them, have been set together, and tightened up by means of screw-bolts, and when the small distributing-pipes have been connected with the supply-pipe, and the pump has been set in motion, the slip is drawn from the store-tank, and forced successively into the 24 bags. As more and more of the slip is driven in, the pressure in the bags is increased, which is resisted by the strength of the calico, the wooden framework, and the tie-bolts. The pressure causes the water to separate from the clay, and filter through the calico, and, passing through openings in the wooden framework, to run in a channel beneath the press into a tank placed for its reception, whence it is pumped for use in the "blungers" or elsewhere. When the water ceases to flow from the bags, the pump is checked, the main supply-pipe is disconnected from the distributing-pipes, the tie-bolts are loosened, and the frames are separated. When the calico between the frames is unfolded, a thin sheet of plastic clay, corrugated by the ridges in the wooden frames, is discovered. In order to prevent loss during the action of the pump, through the bursting of any one of the bags, each of the small distributing-pipes is furnished with a stop-valve, by which its connection with the supply-pipe can be closed, without interfering with the process of filtration in the remainder of the bags.

The clay or clay mixture is now practically pure, and requires only to be freed from the air which is still retained in its pores, and to be rendered close-grained and tenacious. This result is obtained partly by a mechanical and partly by a manual process. The mechanical process is performed by the "pug-mill," Fig. 1140. It consists externally of a conical, cast-iron, horizontal case, with a hopper on the upper part of the large end of the cone, and with a comparatively small square or octagonal orifice on one side of the small end. A shaft passes through the length of the cone, having iron splayed blades fixed spirally round it. The shaft is driven by power, and the clay, which is thrown into the hopper, is mangled and driven forwards by the revolving blades. The shape of the mill causes the clay to be more and more compressed, until it issues from the orifice in a compact stream. The stream of clay is cut into blocks by a tightened wire, and the blocks are conveyed to the different workshops. The manual process of compression is only necessary for clay which is intended for the finest work. It consists in placing the block of clay, as it comes from the pug-mill, on a bed of plaster, and repeatedly cutting it horizontally with a wire, and hurling one half upon the other with all the power the operator can muster.

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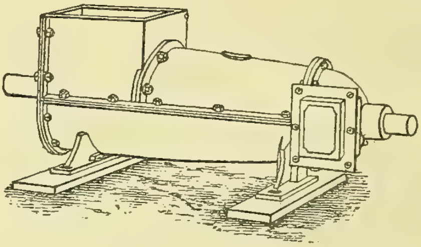

Processes of Manipulation.—*Throwing.*—The process of "throwing" is the application of the principle of "turning" to a plastic material, the turner's tools being replaced by the more delicate fingers of the "thrower." The main apparatus, or "wheel," consists of a horizontal disc, rigidly fixed on the top of a vertical spindle, to which, rotatory motion can be communicated. In addition to the wheel, the thrower has a balance, in which the pattern to be reproduced is counterpoised by the lump of clay from which the reproduction is to be made. The pattern generally only bears a very slight resemblance to the finished article, as ware is now seldom finished on the wheel, but subsequently passes through the turner's hands, by whom it is sometimes reduced to one-half its original substance. As a rule, except in the case of fine stone-ware, the "thrower" gives the inside form only, and leaves the outside to be fashioned by the "turner."

A box to sit upon, a basin full of water, a movable gauge, with a horizontally-revolving needle or pointer conveniently placed for comparison with ware during manipulation, together with a few pieces of thin horn or wood, complete a thrower's equipment. The weighed mass of clay is dipped into the basin of water, and thrown upon the disc, which is sometimes made of copper, sometimes of wood. The disc revolves, and the clay, hollowed by the pressure of the thrower's fingers, rises and falls, contracts and expands, according to the velocity of the wheel and the touch of the thrower. When the vessel attains the height indicated by his gauge, and the requisite form, and has been smoothed from ridges within and without by the pressure of yielding fragments of horn or wood, the wheel is checked, and the vessel, severed from the disc by a fine tightly-drawn wire, is removed by an assistant to the drying-room, where it is partially dried previous to being finished by the turner.

Turning.—The turner's lathe in many respects resembles that employed for turning wood or metal. The vessel to be turned is fixed by a small rim of moist clay upon a wooden block, fitting the interior of the vessel, and projecting from a horizontal spindle, to which, motion can be communicated. The tools employed are thin slips of metal or horn, and a polisher consisting of a piece of Parian ware; sometimes a metallic profile is used, and pressed against the revolving vessel. The turner reduces the superfluous substance of the vessel, and finishes the exterior, the bottom, and the rim; he also, when necessary, polishes the surface. After turning, the ware is replaced in the drying-room, previous to being fitted with handles, spouts, or applied decoration. Before removal, however, the internal form of small open ware, as, for instance, cups, is corrected by pressure upon a wooden cone.

Drying.—The drying-room, to which reference has been made, was originally a 10-ft. brick chamber, with a central stove, and shelves upon the walls for the reception of ware. For the placing and removal of ware, boys had to be repeatedly entering this chamber, a practice which was both laborious and unhealthy. Many contrivances have been devised to do away with the necessity of entering the drying-room, by causing a movable frame to carry the ware from the entrance of the room through the heated atmosphere, and back to the entrance for removal. The best known drying-apparatus is that invented by Colin Minton Campbell, and represented in Figs. 1141, 1142. The heat is supplied to the drying-chamber by the waste or exhaust steam from a steam-engine through the flues V, W, and X. In the centre of the chamber, is a vertical axis E, from which, project horizontal arms D, attached below to the collar P, and above, by the sloping rods G, to the collar F; they carry at their outer ends a circular rack H I, whose outer edge comes within a short distance of the outer wall of the drying-chamber. In this wall is an opening, covered by a sliding-door A B, through which the ware can be placed upon or removed from the rack. The rack is made with several shelves one above another, and each shelf is made of two concentric strips of wood, with space between, to facilitate the circulation of the heat. The shelves are divided into compartments, by vertical partitions running from top to bottom. The machine moves easily on its axis, and a touch of the hand will cause it to revolve, and expose one compartment after another. Fig. 1143 shows another arrangement, in which, pans supporting the ware are loosely suspended, in the same manner as scale-pans, from transverse bars fixed to the transverse circumference of a large, revolving, perpendicular wheel. The wheel is wide, and the pans hang between its two sides; the bases of the pans remain horizontal by force of gravitation during the entire revolution of the wheel.

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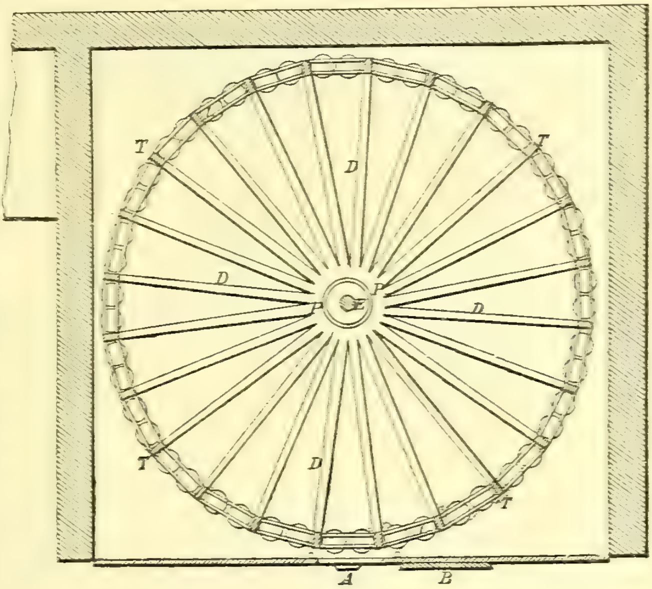
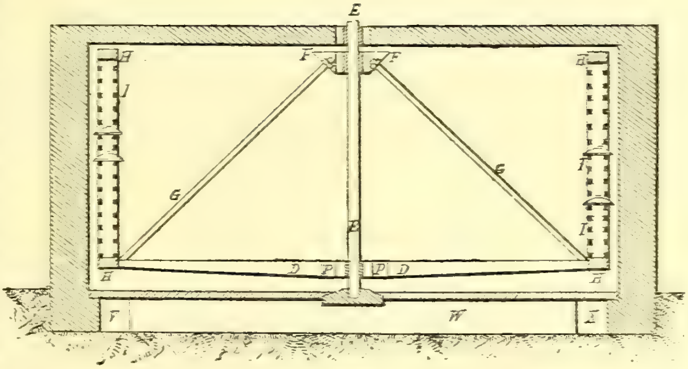


Handles.—Handles are always formed separately from the ware to which they are to be attached, and may be made in several ways. Those which have the same section throughout are cut from a long strip of clay, which has been forced through a metallic template of the requisite shape, placed at the base of a conical case, in which, works a plunger driven by a screw and fly-wheel (Fig. 1144). Ornamental decorated handles are formed by pressing the plastic clay into moulds of plaster of Paris; and light hollow handles, by the injection of a liquid clay mixture into a mould of plaster, and by the deposition of the clay upon the porous surface of the mould (compare Casting, p. 1596). Handle, spout, or whatever is applied to ware in this stage, is fixed by liquid slip, every trace of the joint being carefully removed. At this stage, also, any holes that may be required, as, for instance, in the strainers of tea-pots, are pierced. In the latter case, all the holes are pierced at one blow, by a tool with an equivalent number of points.



1142.

Moulds.—Reference has already been made to plaster of Paris moulds. Few, except the smallest vessels, are made by the thrower, the great majority being formed in moulds. The moulds therefore form the most valuable and, at the same time, the most cumbrous element in the potter's plant. The material of which the moulds are made is plaster of Paris, which is preferred on account of its power, when dry, of absorbing moisture from the clay in contact with it, also on account of the ease with which it can be manipulated. Any number of moulds can be made successively from one model prepared in clay or plaster of Paris, by simply pouring the plaster, rendered liquid by admixture with water, over the model, and allowing it to set. If the surface of the model be covered with a pattern in relief, the mould will have the same pattern impressed, and the clay ware will have the same pattern in relief. In this way, the raised basket-ware, fluted, and flower and leaf patterns on common ware are produced.

Batting.—The process of moulding or "pressing" consists first in forming thin layers or bats of clay, and then inserting and pressing them into moulds, which are generally in two pieces, to facilitate the insertion of the "bats," and the removal of the moulded ware. Bats of clay are formed by hammering out blocks of clay on a bed of plaster of Paris, with a wooden 10-lb. mallet, of the shape represented in Fig. 1145, or by machinery. The employment of machinery is desirable, as the process of hand-batting is both slow and laborious. In the batting-machine represented in Fig. 1146, the clay is pressed between two iron discs with surfaces of plaster of Paris. The upper disc rises from and falls upon the lower stationary disc by means of cranks driven by power. The thickness of the resultant "bat" can be regulated by set-screws; the clay is fed into the small hopper shown in the figure, which opens automatically, to allow the clay to fall upon the lower disc when the upper disc is at its highest point. A modified form of this machine has been introduced, in which are three stationary discs, fixed upon a revolving table, in such a manner that they are successively carried by the table under an upper disc, to which an up-and-down motion is supplied, as in the single batting-machine, already described.

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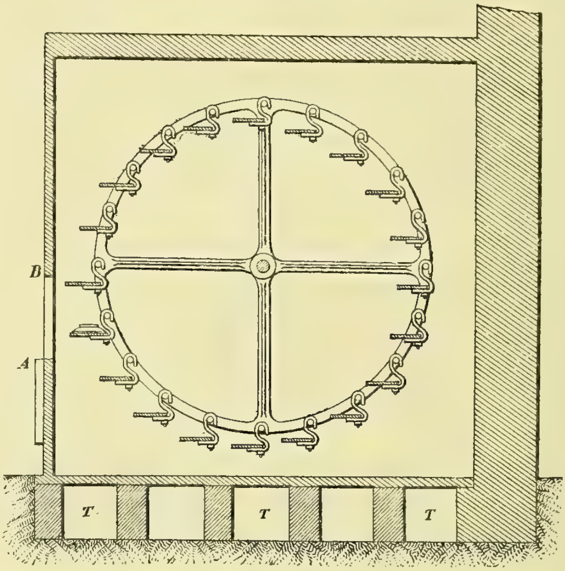

Pressing.—The simplest form of pressing is that employed in the manufacture of plates, and is known as "flat-pressing." The mould is an exact reproduction in plaster of Paris of the inside of the plate to be produced. It is placed upon a block of plaster of Paris, held by four bent wrought-iron arms attached to a vertical spindle, to which, motion is supplied either by hand connected with a large vertical wheel turned by a handle, or by the friction of an endless band driven by power. In the latter case, a pulley is fixed to the lower end of the spindle, to which the band can be transferred from another free pulley, on which the band travels when the spindle is not in use. This band is transferred by the pressure of the operator's knee upon a lever connected with the free pulley. The spindle with the iron frame and plaster head is known as a "jigger." The old process was to place upon the plaster mould a bat of clay, to press it with the hand until its internal surface assumed the form of the mould, that is the form of the inside of the plate, and then to press upon the upper surface of the clay a template or profile having the exact form of the bottom of the plate, the pressure and profile being applied whilst the spindle was in motion.

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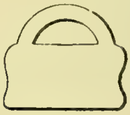
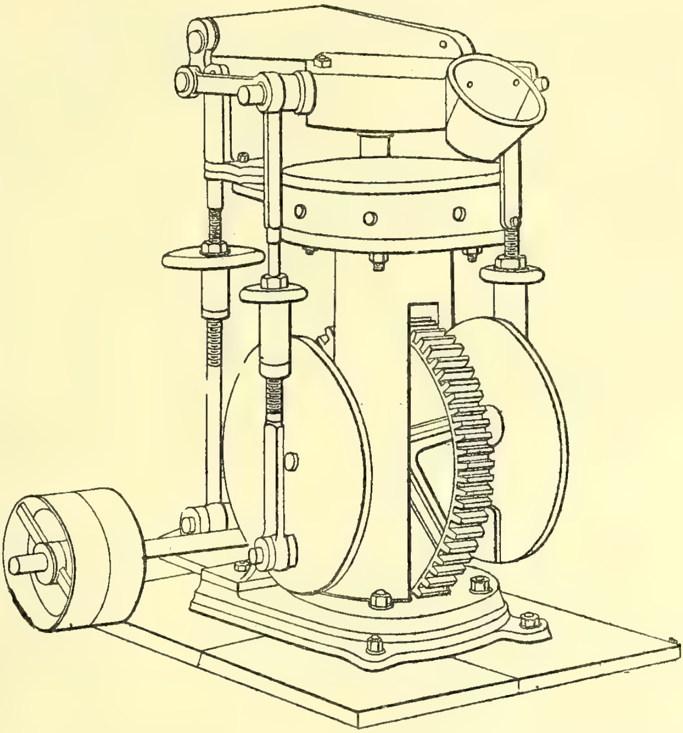


If the spindle be driven by power, the whole operation can be accomplished at once. The profile (Fig. 1147) is fixed to the end of a movable arm, carried by an upright support screwed to the bench through which the spindle works. The arm and the profile can be adjusted at any required height above the mould, and the profile can be pressed upon the clay as it revolves on the "jigger" head, by the handle shown in the figure. After the plate has been formed, it is removed with the mould to the drying-room, and another mould is substituted. Figs. 1148, 1149 show another case of a profile for shaping the inside respectively of a simple and an under-cut vessel. In each, a bat of clay is carefully placed inside a plaster mould fixed on a jigger-head. The profile A (Fig. 1148), attached to the rod B, counterpoised by the weight D, is controlled by the handle C. The jigger-head P, turning upon the spindle L, supports an apparatus for fixing the mould M.

By means of screws passing through the blocks G H, and pressing upon the rubbers I, the mould can be placed in any desired position upon the jigger-head, and eccentrically to the profile. In Fig. 1149, the profile S turns upon an axis, and can be forced into the clay, or withdrawn, as required. If the jigger be set in motion, and the handle be pressed so that the profile be driven into the clay, the vessel will have on its outside the form of the mould, and on its inside the form given by the profile. The mould is made in two pieces, so as to permit the delivery of the vessel. A machine has been introduced for applying an automatic profile to a succession of vessels carried upon a revolving table, each vessel being held in a separate mould and jigger-head. The moulds for ewers, and other vessels of similar shape, are made in two halves; bats of clay are skilfully laid in both halves, and adapted to the form by means of a sponge and scraper; the two halves of the mould are then united (see Fig. 1150) and fastened by a strap, and the complete mould is placed upon a horizontal wheel moved by hand. The seams formed by the junction of the sides of the two bats of clay in the two halves are scraped down by the workman's thumb, there being free access to the interior both from the top and bottom of the mould. The depressions thus made are filled up with rolls of plastic clay, and the internal surface is made perfectly smooth by the application of a moistened sponge. The base of the ewer is made separately on a mould fixed upon a jigger-head, and has a ring of plastic clay placed on its surface, which exactly fits into the bottom opening

1146.



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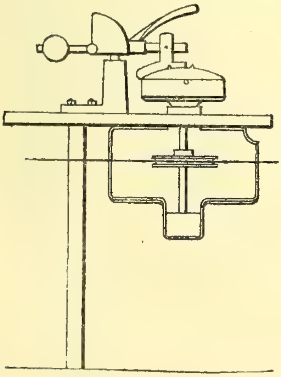

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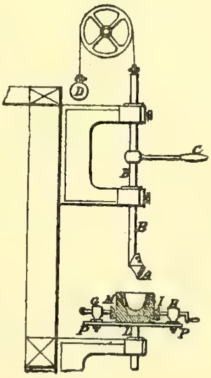

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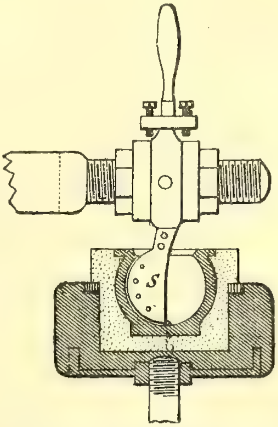
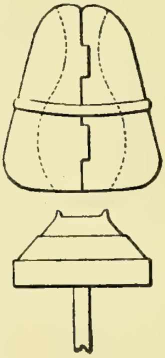


of the body of the ewer. The body of the ewer in its mould is placed upon the base, and the junction is made smooth and secure by welding the raised ridge on the base into the internal surface of the body. In forming tureens, and other deep open vessels (see Fig. 1151), whether round or oval, the bats of clay are adjusted upon a plaster block, covered with coarse flannel, of the form of the interior of the vessel to be produced; upon this block, they are inserted into the mould which gives the external form of the vessel. For oval vessels, specially-constructed jiggers and wheels are required. Their motion is adapted to this purpose by the introduction of an eccentric.

1150.



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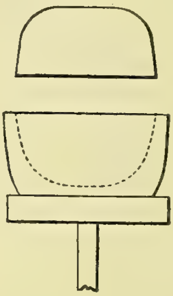
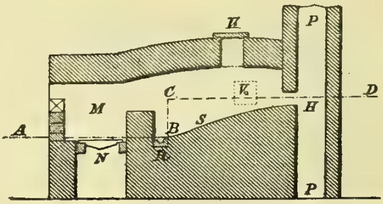


Burning.—When the goods are partially dried, they are trimmed, and when thoroughly dry, are packed in deep round or oval saggers (compare Fire-ware) to be burnt. At the bottom of each sagger, is spread a layer of calcined flint or pure sand, and the goods are packed with the greatest care. For plates, a burnt plate is placed at the bottom, and others are piled upon it. Wide-mouthed and handled wares have burnt rings of the required shape inserted in them, to prevent distortion. The saggers, thus packed, are piled one above another, the interstices being filled by rolls of clay expressed by a small screw-press, until the kiln is full (compare Kilns, p. 1563). The progress of the burning is ascertained by the periodical withdrawal of test-pieces. The firing lasts 48–50 hours. When the firing is complete, and the kiln is sufficiently cooled, the saggers are unpacked, and the ware is rubbed over with sand-paper, preparatory to printing or glazing.

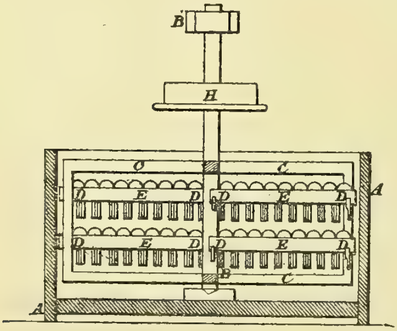
Printing.—See section on Decoration, p. 1597.

1152.



Glazing.—For the glaze, a mixture of borax, Cornish stone, calcic carbonate, flint, and kaolin, is first fused in a small reverberatory furnace, shown in section in Fig. 1152: A is the stoke-hole; M, fire-place; N, grate; K, damper; H S B, bed on which the mixture rests, having been thrown in at V; P, chimney; R, opening by which the mixture, when thoroughly fused, is run out into an iron vessel containing water. The molten mass is broken up by the cold water, and is transferred to small mills, similar to those employed for grinding flint and Cornish stone. After prolonged grinding with water, and passing through sieves of great fineness, it is purified by agitation in a

1153.



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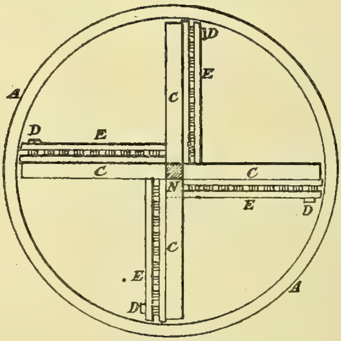
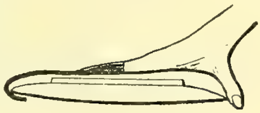


blunger armed with horse-shoe magnets, Figs. 1153, 1154: B is a vertical axis driven from the pulley H; C, four arms projecting from the axis; E, bars fastened by the bolts D to the arms C, and holding the magnets, as shown. A proportion of this slip is mixed with a slip consisting of Cornish stone and plumbic carbonate, or an equivalent of plumbic oxide. Into this liquid mixture contained in convenient tanks, the wares rendered porous by burning are dipped; the mixture is kept in constant agitation, and the porosity of the ware ensures enough being taken up to produce a sufficient glaze. Considerable skill is required to dip the different forms of ware in such a manner that the glaze may be equally distributed, and as little surface as possible be covered by the dipper's hand. Fig. 1155 shows an arrangement, consisting of a thimble with a hook attached, for enabling the dipper to handle with facility plates and other vessels of large diameter. When the parts that have been rubbed, or insufficiently covered with the liquid glaze, have been retouched, and the ware has been thoroughly dried, it is replaced in saggers, preparatory to the fusion of the glaze.

The ware can no longer be packed one piece upon another, as in the previous firing, for the fusion of the glaze would cause the pieces to adhere, and great damage would ensue. The ware is therefore separated by the insertion of props of refractory clay, made in such form that as small a part of the ware as possible shall be touched. Fig. 1156 shows a pile of plates, tiles, or saucers, supported and separated by hollow thimbles with pointed arms. The saggers with their contents are built up in a kiln similar to the one employed for the first firing, only somewhat smaller. The saggers, as in the previous case, are made airtight by the insertion of rolls of plastic clay. The firing lasts some 18 hours, and its progress is tested by the removal of pieces of ware, similar to that being fired, and previously dipped in the same glaze. The test-pieces are usually made on purpose, and pierced in the centre to facilitate removal.

1155.



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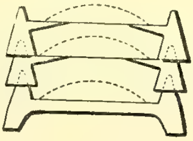
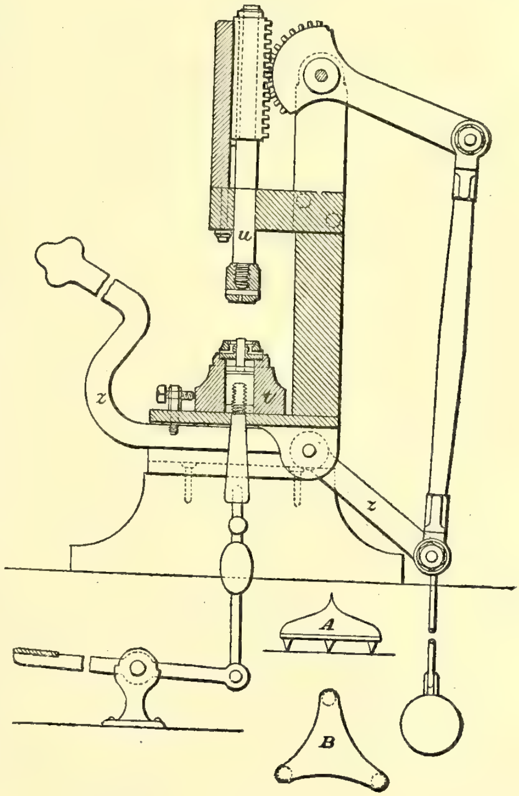


Supports.—Great ingenuity has been expended in devising and manufacturing the supports for ware undergoing the firing for glaze. Fig. 1157 represents a press for forming the supports of stilts A B. The arm and handle *z* turn rigidly upon their axis. If the handle be depressed, the vertical rod *u* is also depressed. When pressure is removed from the handle, the rod *u* is raised once more by the action of a counterpoise. When *u* is in the position shown in the figure, a strip of plastic refractory clay is placed upon the die or mould, and is forced to adapt itself to the form of the mould and plunger, by the pressure of the descending rod *u*, to which the plunger is attached. When the pressure is removed by the action of the counterpoise, the formed support may be raised from the mould by depressing the treadle. Minute apertures are pierced both in the mould and plunger, to permit the escape of imprisoned air, and consequently to ensure the sharpness of outline of the support or cockspur. Machines are now in use which produce 100 supports in one action. The moulds, as in the press already described, are in two halves, one being attached to a plunger, and the other movable. The moulds contain the number of impressions sufficient to produce the required number of supports. There are several duplicates of the lower movable half of the mould, and in this alone are the apertures for the escape of the air. The clay is supplied in a continuous stream from a miniature expressing-machine. After the clay has been inserted, and pressure applied, the lower part of the mould, which contains the supports, is removed, and another is substituted. The mould and supports are heated, and the supports are readily extracted as soon as the clay begins to contract.

1157.



After the supports are removed, the apertures in the depressions are cleared by pressing the mould upon a tool containing an equivalent number of points. The mould is then rubbed with mineral oil, and replaced under the plunger. Supports require to be burnt in the same manner as ordinary earthen-ware.

Terra-cotta and Architectural Pottery.—Terra-cotta is a term commonly applied to works having an artistic character, made of clay, and burnt, sometimes painted and glazed, but more frequently unglazed. The fabrication of fictile works known by this name was common to all the great nations of antiquity; and of late years, much progress has been made in England, France, Germany, Italy, and other countries, in reviving the manufacture of useful, ornamental, and domestic articles in terra-cotta, and in applying this material to architectural purposes.

The clay anciently used in the small vessels and ornaments is fine in texture; the larger pieces are made of rather coarser clay, combined with pulverized lava, pumice, or potsherds. They are generally much lighter than modern works of a like size. Some of the ancient pottery commonly called "Samian ware," of a beautiful coralline red, we have never perfectly imitated; there is much yet to discover relating to ancient pottery of this class. Vauquelin made analyses of fragments of Greek terra-cotta, and gives the following as some of the constituents:—Silica, 53 per cent.; alumina, 15; lime, 8; oxide of iron, &c., 24.

Between the 12th and 14th centuries, large and sumptuous edifices were erected in N. Italy of brick and terra-cotta, the latter taking the place of stone and marble for cornices, panels, string courses, and brackets. Many examples of brick buildings with terra-cotta mouldings and ornaments exist in England, having been erected mostly between the 13th and 16th centuries. Generally the use of terra-cotta died out in this country with the Tudors, and except a slight revival of moulded brickwork about the 17th and beginning of the 18th century, architectural terra-cotta was not practised until the time of George III. Towards the close of the 18th century, coeval with the great improvements made by Wedgwood in pottery, a most important advance for reviving the use of terra-cotta was established in Pedlar's Acre, Lambeth, by a lady named Coade. At these works, capitals and bases of columns, coats-of-arms, pedestals, friezes, bases, statues, balustrades, archivolts, and terminals, were made; and at the commencement of the present century, terra-cottas from Coade's works were to be met with in all the best parts of London and the provincial towns. Sculptors were employed upon models for this pottery, some of whom afterwards took to manufacturing terra-cotta on their own account. Among them was Rossi, who executed statues, capitals, and other ornaments in terra-cotta for St. Pancras church; and Bubb, who modelled and made the frieze in front of Her Majesty's Theatre, and most of the statues on the cornices, and in the tympani of pediments in Regent's Park.

Early in the present century, a manufactory was also opened at Bow, to make church-yard monuments and architectural details in terra-cotta, by Van Spangen and Powell; but it was soon closed. Some small works were opened also in various country places, but with little success. A few years prior to the International Exhibition of 1851, an inquiry sprang up for architectural details and garden ornaments, which caused the production of many excellent examples for the Exhibition. These came from many places in England, and some from Ireland and Scotland; nearly every class and variety of terra-cotta then manufactured found a place, and the specimens from France, Germany, Italy, and Switzerland were numerous.

Very little terra-cotta was painted and enamelled in the 18th century, and we are only now beginning to imitate the enamelled terra-cotta of the 14th, 15th, and 16th centuries. Since 1851, the use of terra-cotta has very largely increased in England, and it has now become a staple building-material, besides branching out in innumerable directions for ornamental and useful purposes. Considerable quantities of English terra-cotta have been exported during the past 25 years to India, Australia, New Zealand, and the United States. Within the past 10 years, the Americans have established several manufactories for this ware.

Red terra-cotta mouldings are now used in combination with red brick-work in all parts of England, and the making of moulded bricks of this class is a special business. Machinery is employed in this work, but the more ornamental and artistic pieces are pressed into plaster moulds; so also are buff and white bricks, which are coloured and enamelled for string courses and dados. White, buff, brown, red, and other clays of various tones are now used for ornamental works, and for busts, statuettes, relievi, and architectural details. The painting, gilding and enamelling of terra-cotta is rapidly improving, and thus employment of a highly artistic character is afforded to women. Busts and statuettes are to be seen in the Royal Academy Exhibitions modelled in terra-cotta clay, and fine as original works fresh from the touch of the sculptor, without the process of moulding. Architects and sculptors are paying much attention to this subject of original modelling in terra-cotta, and we may hope very soon to rival the works of Lucca della Robbia, Bernard Pallissy, and other old masters. It may be interesting here to introduce Brogniart's analysis of the clay bodies of the two great modellers just named, before giving a statement of analyses of English clays used in terra-cotta, and a list of clays especially fitted for this material. Brogniart gives the following as the elements of the wares of:—

	Lucca della Robbia.	Pallissy.
Silica	49·65	67·50
Aluminá	15·50	28·51
Lime	22·40	1·52
Magnesia	0·17	..
Oxide of Iron	3·70	2·05
Loss	8·58	0·42
	100·00	100·00

Table of Analyses of some Clays used for Terra-Cotta and Tiles.

Constituents.	Names of Clays and Places where they are found, and Name of Analyst.											
	Blue Barrow, Cornwall, Dr. Lyon Playfair.	Bovey, Teignmouth, Mr. W. Weston.	Blue Ball, Bovey Tracey, Mr. Blake.	Blue Clay, Wareham, Mr. W. Weston.	Buff Clay, Wakerley, Dr. H. Medlock.	Oolitic Clay, Northampton, Dr. H. Medlock.	Red Clay, Watcombe, Dr. Percy.	Red Clay, Broseley, Johnson.	Red, Dunfermline.	Red, Manton, Dr. H. Medlock.	Red London Clay.	Mud of the Thames (burnt dark red), Dr. Lyon Playfair.
Silica	45·52	52·06	47·0	48·99	69·59	75·78	57·83	64·06	64·14	54·40	50·40	44·15
Alumina	40·76	29·38	48·0	32·11	20·04	15·61	20·55	20·60	13·34	18·58	24·00	11·27
Iron	..	2·37	1·5	2·34	3·37	3·54	7·75	7·16	7·57	11·75	..	5·95
Lime	2·17	0·43	..	0·43	3·16	2·12	1·68	0·12	1·90	2·48	2·70	17·02
Magnesia	traces	0·20	2·0	0·22	3·18	2·40	0 97	0·04	..	3·41	1·30	2·25
Titanic acid	..	..	..	..	..	..	..	0·62	..	..	..	..
Carbonic acid ..	..	..	..	..	..	..	0·90	..	..	..	..	..
Phosphoric acid ..	..	..	..	..	..	..	traces	..	..	..	..	..
Potash	1·90	2·29	..	3·31	..	..	3·87	0·91	1·54	8·53}	..	1·30
Soda	..	..	..	..	..	..	0·56	0·44	..			
Manganese	..	..	..	..	traces	traces	traces	0·09	..	trace	..	..
Sulphate of lime ..	..	..	..	..	..	..	..	..	..	..	..	4·53
Phosphate of lime	..	..	..	..	..	..	..	..	..	..	..	0·72
Organic matter ..	..	..	..	..	..	..	4·39	traces	..	..	..	9·15
Loss and water ..	9·61	12·83	1·5	11·96	..	..	2·13	5·85	..	..	21·60	3·66
	99·96	99·38	100·0	99·36	99·34	99·45	100·63	99·89	88·69	99·15	100·00	100·00

All these clays will stand fire well, and are much used. In addition, the following are in common use for ornamental and moulded work, and for tiles:—Stone-ware, black and red clays, from Wareham; red and buff clays from near Tamworth, Staffordshire Potteries, Bishops Waltham, N. Shields, Aldrington and Brighton, Leeds, Huntingdon, Arley, Worcester, Tamar; red clays from Broseley (Shropshire), Ipswich, Penybont, Knutsford (Cheshire), Northwich, Farnham, Maidenhead, Bucknell (Berks), Norwich, and Pluckley (Kent). The Cornish, Devon, Dorset, and other clays which burn to a light colour, as a rule will stand a higher degree of heat than the red clays, and generally shrink less in the fire. There is great difference in the weight of clays when dried and ground; in some, as much as 25 per cent. All are improved by weathering, and, after tempering and mixing, by age. Many of the strong red clays become blue under certain conditions of burning, and some become readily discoloured. Great care is necessary in firing red ware to maintain a uniformity of tone, and avoid cracking and warping. Red terra-cotta in some cases is improved by combining two or more clays. Black, chocolate, and other dark colours have red clay as the base, to which is added calcined ochre, manganese, and other substances.

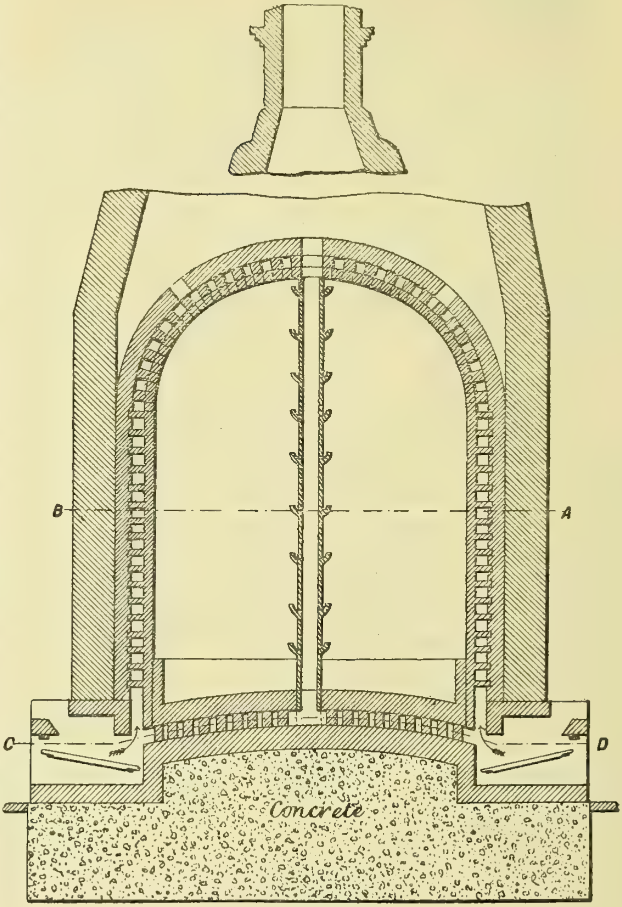
Many clays are very pure, and do not require washing; some, however, contain pyrites, or other substances which necessitate careful washing through sieves, or what is termed "slipping." Coloured bodies for terra-cotta or tiles should be always mixed in the slip state, and brought to a proper consistency for working on a slip-kiln. Many clay bodies are now, after slipping, passed through machines constructed to press out the superfluous water, and leave the clay in a pasty state fit for immediate use. Some manufacturers only partially dry the clay, then crush it in a rolling-mill, mixing with it ground potsherds, sand, &c., and then pass the whole through a pug-mill. Others dry the clay thoroughly, and grind it to powder between horizontal stones, mix what they desire with it, and then pug the whole, occasionally passing it twice through the pug-mill. When different clays are combined in the dry state to make one body, it is important this should be done. Clays used for mouldings are often pugged as taken from the pit, and at once transferred to a moulder's or machine-worker's charge. It is not safe, however, to make very large pieces by machinery.

The material chiefly used in large terra-cotta to check warping, unequal shrinkage, and cracking, is ground burnt clay, old ware, or potsherds. This material is sometimes called by the workmen "grog," at other times "grit." It is ground and passed through sieves of various meshes to suit the character of the work in point of magnitude and delicacy of ornamentation. Clay is sometimes mixed, kneaded, and burned especially for this use. The proportions to be used vary according to the size of the pieces to be made, the quantity of other substances (if any) to be combined, and the fatness of the clay. After the clay is mixed and prepared by the mill, it should for all artistic works be well beaten with an iron bar, and what is termed "wedged," which consists in cutting a lump of clay with a wire, and slapping it together repeatedly to remove the air.

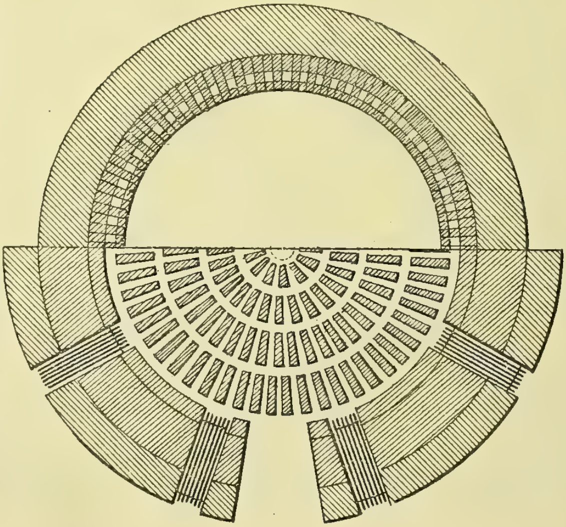
The other materials used besides clay and potsherds vary according to the clay, and the class of terra-cotta it is desired to make. Among these, sand is an important substance. Ground glass, china stone, and flint are often used. Generally clay itself forms, in light-coloured ware, about $\frac{2}{3}$ of the composition, and for good red clays, sand or flint is commonly all that is required to be added, unless the pieces are large.

Kilns. — Before entering

1158.



1159.



upon the subject of modelling, or moulding, it will probably be best to speak of the kilns for burning the ware (Figs. 1158, 1159). These are usually round in plan, with an internal dome and a conical chimney. They are lined with fire-bricks, and banded with iron, which is arranged to fold, and fasten over the door of the kiln, when the firing goes on. The number of furnace-holes around the kiln is determined by its size. Flues pass from the lower parts of the furnaces, under the floor of the kiln, and are commonly in connection with a fire-clay pipe-flue in the centre, as shown in Fig. 1158, which represents the section of a kiln with a continuous muffle, or inner lining, for the prevention of discoloration of the articles burned by vapours from the coals, also for the better protection of coloured and glazed articles. For all ordinary terra-cotta, this inner casing of brick or muffle throughout is not necessary. Small delicate models, whether plain or painted, enamelled or gilt, should be placed in saggers, if burnt in a kiln without a muffle. Articles beautifully wrought are made of stone-ware clay, painted, fired, and glazed with the vapours from salt, as in the manufacture of stone-ware. It has been found that burning by wood produces different results from firing salt-glaze with coal. Furnace-holes are constructed to check or prevent the formation of smoke. When a large volume of smoke is formed in the furnaces, it will pass through the kiln in full fire and red hot, and come out black at the top.

Modelling.—Before commencing any architectural work, full-size drawings should be made of all the details, and, to save errors, this had better be done to the terra-cotta scale of the wet clay, allowing for shrinkage in drying and burning; this with buff clays, is about 1 in. to 1 ft., but the extent of contraction after careful firing should be determined exactly, at the outset, before any work is set out, or model made. From the drawings, sections of the mouldings may be traced on wood or metal, for forming templates or running moulds, similar to those used in working plaster cornices. Such templates, worked against the edge of a rule fixed to a board or bench, can be used to form mouldings in clay, and, worked from a centre, for describing arches and circular forms. The clay used may be the terra-cotta clay itself, and this mode of working is the cheapest when a small quantity is wanted of a given moulding, as the whole may be described at one time. When the clay has become stiff, it can be cut into various lengths, and fitted with angles if necessary, and so left to dry for burning. If the mouldings are large, they should be hollowed out. A thickness of 2 in. is usually sufficient for the largest mouldings. Considerable attention should be paid to the drying of the mouldings, or they will warp, or get out of shape. By turning them about, face, and sides downwards, and then reversing their position, until they are dry, they may be kept true. The clay used in running mouldings in this way should not be coarser than would pass through a sieve of 20 meshes to the lineal inch, or the arrises will not be brought out sharply. Mouldings may be dried before burning, until they are hard enough to be rubbed true with a piece of burnt terra-cotta, as masons rub the surface of Bath and other stones. They seldom twist in the fire after perfect drying and rubbing, and the mitres and junctions can be delicately finished by the chisel, so as to fit with accuracy. This operation of perfect drying and rubbing applies to all plain terra-cotta surfaces, whether prepared by the process of running moulds, or by machines similar to brick-machines, or from plaster moulds.

Plaster of Paris models prepared by templates should be made to the required scale when a large repetition of the same object is likely to be required, and more than one plaster mould wanted for making clay impressions. Plaster is the best ground or framework for clay models of enrichments and bassi relievi, when more than one piece of the same ornamental design is required. The combined clay and plaster model are readily moulded with plaster in the ordinary way. If the model is entirely in clay, and full of undercut foliated work, say in alto relievo, or a statue, many pieces would be required in such a mould, and an experienced plaster-moulder only should be employed, or the clay model may be spoilt. It is best to make as few pieces as possible, and arrange to get, whenever practicable, all the small pieces into two outside cases, the back of a statue in one case, and the front in another case. Grease or oil should not be used in making plaster moulds for terra-cotta, as is done in the common way of making plaster piece-moulds for casting. A little clay and water, mixed about as thick as good milk, will answer all purposes for the prevention of one piece of plaster sticking to another in piece-moulding.

Original, life-size, terra-cotta statues are modelled and burned, without the process of moulding, by building up the clay in a cellular form, and working with the fingers and modelling-tools on the surface. Extended limbs should be made solid in the first instance, and when the clay is stiff, hollowed out, jointed with soft clay to the body of the figure, propped up with clay supports of the same stiffness and age as the mass of the statue, and slowly dried for the firing. Some difficulties and dangers arise in moving large statues into a kiln, and frequently they are finished by the sculptor in the kiln, which is for the time illuminated by gas.

Very large fountain-basins and vases are made by forming on a bench, with a trap-door in the middle, the core, or inside, with clay worked by a template from the centre. When the core is turned in this way, it should be covered with thin sheets of paper, and upon this paper the outer surface of the basin is turned with another template from the centre, by laying sheets of clay over the prepared surface of fairly uniform thickness, pressing and uniting this outer clay which forms the basin well together. The template will now turn the outside of the basin. When the clay has stiffened, ornament may be modelled on the surface, or pieces of enrichment, made from plaster moulds, may be luted on with clay slip. It will be observed that, during this process, the basin is upside down, and is resting partly on the clay core. After the clay has become tough, the trap-door in the centre of the bench may be removed from beneath, and the clay core pulled away in pieces, leaving the basin gradually to dry alone; when dry, it should be turned over very carefully, examined as to finish and truth of surface, and removed to the kiln, resting only on a roll or disc of clay at the bottom, leaving the rim and upper portion quite free for equal contraction in burning. Basins, vases, and other articles, 12–20 ft. in circumference, have been made sound and true in every respect in the way described.

Many persons have a just objection to the piracy of architectural details especially modelled for their own use. Working such details out originally in terra-cotta is a check to this piracy. If an artistic work is executed in marble or stone, a model in common clay is made and moulded, and a plaster cast is taken to guide the carver, and this rough model is often used for all sorts of cement and composition castings. But the terra-cotta clay model is wrought out, undercut, and finished at once by the sculptor and burned, and when only one or two designs alike are required, it is in a money sense the cheapest and best method of working. The following are a few of the forms which can be safely and economically made as original terra-cottas:—Altars, arches, architraves, balconies, brackets, bassi relievi, bosses, busts, columns, capitals, chimneys, crosses, cornices, coats-of-arms, finials, fire-places, friezes, park seats, key-stones, medallions, tracery, perforated panels, rustic work, tablets, tombs, animals, canopies, caryatides, festoons, statues, trophies, scrolls, corbels, date tablets, terminals.

When much repetition is required, the use of plaster moulds is common; now and then, for flat surfaces, metallic and wooden moulds are used. The workmen employed in making impressions in moulds are called "moulders." The plaster mould is usually dusted with a little finely-ground flint, grit, or sand, and the clay, having been properly prepared, is beaten out on a very thick block of plaster of Paris, to the required thickness, and then firmly pressed by hand on to the surface of the mould. If the mould is in two parts, or cases, both pieces are partially filled with impressed clay, the edges of such clay are scratched with a tool, moistened with water, and a little soft clay is placed over the edges, when one portion of the mould is lifted over the other, and squeezed down so that the luted edges join perfectly. The clay and the plaster mould remain undisturbed until the porosity of the plaster has absorbed a portion of the water from the clay, when the outside casings and the smaller pieces of the mould are removed, and the article pressed appears showing the joints or seams of the mould on the surface. These are in due time removed by a modeller, or careful finisher. If the pieces to be made are large, struts or cells are formed to strengthen them, as nearly all terra-cotta works are hollow. The hollow parts of architectural details are generally filled up with good stiff mortar, selenitic, Portland, or Roman cement, with fragments of brick or tile. Great care should be taken if Portland cement is used that it does not expand, which it is apt to do, sometimes cracking the terra-cotta.

A very large proportion of the articles made of terra-cotta are dried imperfectly, or in draughty sheds, and hence there are many twisted and unsightly pieces. A good drying-chamber or shed properly heated, and in proximity to the kilns, is a desideratum. More ordinary terra-cotta ware is injured in drying than is spoiled in the firing.

Employment of Machinery.—Terra-cotta mouldings or moulded bricks are sometimes made in a machine acting vertically with a die at the bottom, and as the clay passes from this die, it is caught by a board or palette, and cut off in given lengths, as drain-pipes are. At other times, mouldings and ashlar pieces are driven through dies, out of a brick-machine, cut off by wires and removed on palettes. The mouldings and the ashlar work, when stiff, are trimmed clean at the edges. Ornament pressed out of plaster moulds is sometimes luted or slipped on to the plain mouldings. The completeness of machine-work depends much upon careful drying. All these machine-made mouldings and ashlar work, if dried thoroughly; may be rubbed true, the same as Bath and other stones are treated, as before mentioned. Terra-cotta tiles 12 in. sq. have been made in great quantities by machinery, and rubbed as true as marble.

Fire-proof Terra-cotta.—By the aid of machinery, fire-proof terra-cotta for casing iron columns, girders, and for general construction of walls and floors, may be economically produced. Gas and other stoves, hearths, and backs for fire-places are made of fire-clay, coloured, and glazed. Stove-backs, ornamented with crests and coats-of-arms, have been made of fire-clay in which black oxide of manganese has been introduced, so as to produce, after burning and rubbing with black-lead, the appearance of cast-iron.

Some fire-clays are of a nice pale-buff colour, and free from specks of iron, from which, columns, pilasters, soffits, facias, and slabs could be made by machinery. Such work should be of greater thickness than ordinary terra-cotta, and should be contrived to fit together by mortise and tenon, with lap-joints luted with fire-proof cement, and filled in with fire-proof materials, so as to prevent the sudden destruction by fire and water of iron girders and columns, which almost always ensues in large fires.

All the buff clays used in ordinary terra-cotta are to a certain extent fire-clay, and will stand a temperature at which most of the red clays run down into a vitreous mass. Columns made hollow, of buff terra-cotta clay combined with fire-clay, were used by Sir Digby Wyatt to support girders, and at the same time to act as warming-flues through a building of three floors.

Strength of Terra-cotta.—The results of experiments made to ascertain the resistance of terra-cotta to a thrusting stress, comparatively with Portland and Bath stones and common stock brick, show that, as a building-material, it greatly exceeds all in ordinary use. A table recording these experiments, prepared by David Kirkaldy for J. M. Blashfield, and laid before the Royal Institute of British Architects by Charles Barry, is given on pp. 1588–9. (The specimens were bedded between pieces of pine ½ in. thick.)

Among the public edifices where terra-cotta has been very largely used during the past 30 years, are the following:—S. Kensington Museum, Duchy of Cornwall Office, Royal Mausoleum (Windsor), Victoria and Albert Museum, Sassoon Tower, Elphinstone Circle, and National Bank of India (Bombay), London & N. W. Station, Broad St. (London), Buckingham Palace, Sandringham House, Royal Albert Hall, Wedgwood Institute, India Office, Rolls and Record Office, Dulwich New College, Natural History Museum (S. Kensington), Law Chambers in Carey St., Fine Art Museum (Boston, U.S.A.), New Libraries (S. Kensington), Life Guards Barracks (Knightsbridge).

Tesselated and Tile Pavements.—Such pavements are frequently called mosaic, encaustic, and inlaid. Floors of tesselated work made of common clays are of great antiquity. The mosaic pavements so frequently met with in Roman remains in England are composed of fragments of tile and stones of various hues; the larger tesseræ for the outside margins are commonly clay, and the red invariably so. These pavements, from the inequality of hardness of the materials, have not worn uniformly in all cases.

A special feature in Mauresque mosaics, is the interlacing of one colour with another in the same device. A stanniferous glaze was commonly used by the Moors in the 13th century. The pieces forming their mosaic works, also their tiles with raised ornament, appear to have been pressed into plaster moulds. Glass mosaic, having a Mauresque type of design and colour, is commonly met with in the churches of Italy, and frequently in combination with porphyry. There are examples of this and marble mosaic in Westminster Abbey. Florentine mosaic is composed entirely of marbles, agates, and gems; the materials are costly, and the process of working it slow, but most beautiful pictures are produced at the studios for this art at Florence.

Several attempts were made in England in the beginning of this century to form tesselated pavements by combining marble and stone with coloured cements; Wyatt, Carter, Benasconi, Felix Austen, and Croggon, made attempts in this form, but with no great success. In 1836, Blashfield made ornamental pavements by combining Aspdin's and Parker's cements with mineral colours. This pavement wore well, and stood frost, but it looked dingy. The cements were mixed with water, placed in iron moulds, and screwed down to drive off part of the water from the cement, and so get the edges of the forms perfect. Inlaid tiles after patterns of encaustic clay tiles were so produced, and subsequently Blashfield tried coloured bitumen, but this material did not wear or look so well as the cement. Painted tiles were made in clay by Copeland & Co. at this time for Blashfield for terrace-steps. The tiles were so designed and made that, when combined, they formed a pattern 6 ft. in length. The colours were red and black. In 1839, an elaborate mosaic floor was made by Blashfield at Deepdene, combining the features of the ancient "opus incertum," the Venetian "pisé," and the common Italian "trazzo" floors. It is the largest floor of this character in England. The mosaic features were placed face downwards on a true bench, and backed with thin red tiles and cement, and thus formed into large slabs, which, when all properly bedded on a concrete floor, were rubbed down and polished.

In 1838, Routledge and Greenwood made buff terra-cotta pavement and tiles. The latter were inlaid with scagliola, and polished. In 1839, Singer of Vauxhall, assisted by Pether, made tesseræ for slabs and pavements, copying Moorish and Roman examples. Singer's process was to place clay, well kneaded and of various colours, and as near as practicable of uniform stiffness, in a machine, where, by means of levers, it was subjected to pressure, and made to exude from an aperture 6 in. by ½ in. As it protruded, it was cut into lengths of 3 in., and these small pieces were left for some days to dry. Fifteen or more were then laid one upon another, and a frame of corresponding size (across which were strained wires, crossing one another at regular intervals), sliding vertically on two uprights, was made to pass through them, cutting out by this motion 100 or more tesseræ. When any curved forms were required, the tesseræ were placed angle-wise in a groove, and a piece of curved metal was made to pass through a number of them placed together, which gave a coincidence of form in the parts divided. The tesseræ were then burnt, and put together on slabs of slate. The great hall of the Reform Club was executed by Singer with tesseræ thus

Test No.	Marked.	Description.	Dimensions.		Base Area.	Cracked Slightly.			Cracked Generally.			Crushed.		
						Total.	Per square inch.	Per square foot.	Total.	Per square inch.	Per square foot.	Total.	Per square inch.	Per square foot.
C.			H.	L. B.	Sq. inch.	lbs.	lbs.	Tons.	lbs.	lbs.	Tons.	lbs.	lbs.	Tons.
638	No. 2. 15	Cube, solid	5·90.	5·88×5·90	34·69	238,960	6,888	442	255,350	7,361	473	282,520	8,144	523
639	„	„ „	5·92.	5·90×5·86	34·57	202,730	5,864	377	212,550	6,149	395	224,920	6,506	418
632	MG. 17	„ „	5·78.	5·72×5·74	32·83	132,340	4,031	259	188,840	5,752	369	237,180	7,224	464
633	„	„ „	5·68.	5·70×5·70	32·49	138,120	4,251	273	159,730	4,916	316	163,110	5,020	322
637	CT. 16	„ „	6·00.	5·68×6·21	35·27	128,150	3,633	233	184,240	5,224	335	222,870	6,319	406
636	„	„ „	5·90.	6·10×5·76	35·13	122,350	3,482	223	176,730	5,031	323	183,820	5,232	336
635	CA. 14	„ „	5·95.	5·85×5·80	33·93	133,630	3,938	254	168,110	4,954	318	189,520	5,586	359
634	„	„ „	5·95.	5·85×5·80	33·93	127,150	3,747	240	154,560	4,555	292	176,840	5,212	335
645	MG. 1	Hollow, filled *	6·20.	11·60×5·70	66·12	46,340	701	45	74,220	1,122	72	168,610	2,550	163
646	„	„ empty	6·20.	11·46×5·70	65·32	22,340	342	22	39,720	608	39	80,840	1,238	80
650	CT. 3	„ filled	6·30·	11·70×5·80	67·86	26,250	386	24	54,370	801	51	130,260	1,919	123
649	„	„ empty	6·25.	11·55×5·85	67·56	33,850	353	22	43,630	645	41	69,350	1,026	65
648	CA. 2	„ filled	6·25.	11·70×5·80	67·86	54,120	797	51	84,180	1,240	79	126,970	1,871	120
647	„	„ empty	6·10.	11·70×5·80	67·86	26,740	396	25	44,920	662	42	64,380	938	60
656	MG. 9	„ empty	5·75.	11·55×6·72	77·61	56,540	728	46	178,960	2,305	148	224,750	2,895	186
655	„	„ empty	5·70.	11·55×6·90	79·69	54,370	682	43	166,220	2,085	134	218,630	2,743	176
652	No. 2. 4	„ filled	5·73.	11·70×6·90	80·73	108,100	1,339	86	130,270	1,613	103	148,140	1,835	118
651	„	„ empty	5·75.	11·66×6·90	80·45	53,330	662	42	90,110	1,120	72	127,950	1,590	102
654	CT. 5	„ filled	5·70·	11·60×6·90	80·04	54,830	685	44	118,220	1,477	94	134,510	1,681	108
653	„	„ empty	5·80.	11·60×7·00	81·20	48,680	599	38	60,870	749	48	94,160	1,159	74
669	23	Solid	2·45.	3·40×3·85	13·09	174,120	13,302	855	181,840	13,891	893	188,120	14,371	924
670	22	„	2·80.	3·40×3·85	13·09	53,110	4,057	260	64,330	4,914	316	66,560	5,084	327
674	27	„	4·70.	5·10×2·00	10·20	21,635	2,121	136	51,550	5,054	325	84,380	8,272	531
673	28	„	2·70.	6·50×3·32	21·58	60,530	2,805	180	96,280	4,461	287	117,290	5,435	350

671	Red 20	Nearly solid	2·70.	9·00×4·12	37·08	72,250	1,948	125	98,320	2,651	171	119,870	3,232	208
672	26	,, ,,	4·10.	8·10×1·60	12·96	31,220	2,409	154	33,610	2,593	166	34,840	2,688	172
664	No. 2. 6	Hollow, filled	2·90.	11·90×3·50	41·65	47,060	1,130	72	72,140	1,732	111	146,730	3,523	226
663	,,	,, empty	2·90.	11·90×3·50	41·65	15,525	372	23	21,567	518	33	66,470	1,596	103
658	MG. 7	,, filled	2·85.	11·80×3·50	41·30	49,410	1,196	77	116,100	2,811	181	133,450	3,231	207
657	,,	,, empty	2·85.	11·80×3·50	41.30	16,685	403	25	24,455	592	38	70,775	1,713	110
660	CA. 10	,, ,,	2·90.	11·90×3·50	41·65	10,630	255	16	17,040	409	26	59,115	1,419	91
659	,,	,, ,,	2·90.	11·85×3·50	41·48	9,710	234	15	15,680	378	24	54,370	1,310	84
662	CT. 9	,, ,,	2·87.	11·90×3·50	41·65	7,160	171	11	13,110	314	20	53,550	1,285	82
661	,,	,, ,,	2·87.	11·90×3·50	41·65	6,305	151	10	12,938	262	17	34,715	833	53
668	RC. 8	,, filled	2·90.	11·70×4·00	46·80	36,555	782	50	70,415	1,504	97	118,350	2,529	162
667	,,	,, empty	2·90.	11·70×4·00	46·80	3,342	71	4	7,810	167	10	31,208	666	43
665	CA. 13	,, ,,	3·10.	11·85×4·00	47·40	6,655	140	9	19,880	419	27	35,420	747	48
666	,,	,, ,,	3·10.	11·85×4·00	47·40	6,178	130	8	14,844	313	20	31,980	675	43
640	MG. 11	Column	11·90.	6·60 dia.	34·19	163,122	4,774	307	222,610	6,511	418	258,370	7,572	486
641	,,	,,	12·00.	6·56 dia.	33·82	131,820	3,898	250	143,650	4,247	273	167,880	4,964	319
642	CA. 12	,,	12·00.	6·60 dia.	34·19	128,530	3,759	241	181,760	5,316	342	212,580	6,218	399
643	,,	,,	11·95.	6·60 dia.	34·19	44,840	1,311	84	68,720	2,010	129	88,940	2,601	167
644	Red 24	,,	15·50.	6·00 dia.	28·27	108,170	3,826	246	123,620	4,373	281	137,570	4,866	312
677	19	Hollow, empty	5·50.	18·00×9·70	174·60	44,120	252	16	67,540	387	25	99,880	572	67
675	21	Solid	1·00.	6·10×6·00	36·60	386,350	10,556	679	..	..	..	..	..	..
706	Portland Stone.		6·00.	5·95×5·80	34·51	151,280	4,401	283	156,820	4,544	292	156,820	4,544	292
705	,, ,,		6·00.	5·95×5·85	34·80	150,750	4,332	278	155,540	4,470	287	155,540	4,470	287
708	Bath ,,		5·92.	6·00×5·88	35·28	48,120	1,364	88	57,270	1,623	104	57,270	1,623	104
707	,, ,,		6·00.	5·90×5·90	34·81	45,270	1,305	84	54,880	1,576	101	54,880	1,576	101
710	Common Stock Brick.		2·50.	9·10×4·12	37·49	10,110	270	17	28,660	764	49	47,840	1,276	82
709	,, ,, ,,		2·50.	9·00×4·20	37·80	8,160	216	14	24,220	641	41	44,240	1,170	75

* "Filled" implies that the hollow portions were filled with Roman cement.

made, and ground down to a true surface. He also made a pavement for the court of the present Royal Exchange of similar tesseræ, but being laid down during winter, the cement gave way, and the whole was taken up and removed. Some of the pieces used for dados and Mauresque slabs were made out of plaster moulds, and these were often coloured and enamelled. These pieces of tesseræ were affixed to slabs of slate with plaster, and were much used for sides of stoves. About 1830, S. Wright of Shelton took a patent for making inlaid tiles after the fashion of the mediæval tiles; he sold his rights to Herbert Minton, who, assisted by the advice of Welby Pugin, produced the tiles so well known in connection with the name of Minton.

Inlaid tiles were largely made in England in the 13th, 14th, and 15th centuries, some later on. The oldest tiles are of red or brown colours, some few black, having ornaments painted on them with white or buff clays, and glazed. Other tiles have ornaments impressed on them in relief, possibly pressed in carved wooden or plaster moulds. This impress of ornament may have suggested the inlay of other coloured clays in an indented surface, and led to the running-in of slip, or thin clays of white, buff, black, or green, into the indented surface of the tile. The superfluous slip would have been scraped off when stiff, and the tile brought to a perfect face, and glazed and burnt. All these tiles seem to have been coated with a plombiferous glaze. They were made of various sizes, but are not often found more than 6 in. sq., and frequently are so designed that 4, 9, and 16 tiles are required in combination to form one pattern. Some of the best pavements of this sort were found at Salisbury, Winchester, Exeter, Bristol, Chichester, Oxford, and Gloucester Cathedrals; and in numerous old churches and other places in England they exist in great number. One of the most perfect old examples is the floor of the Chapter House, Westminster Abbey. They are frequently laid with marginal tiles quite plain, and sometimes with an inlaid border at the verge. The inlaid ornament usually affords a clue to the date of the tiles, as the type of the architecture of the age is seen in these fictile records. There is an artistic effect about the free sketchy way in which the designs are drawn, and the mottled appearance of the colour, which gives them a great charm, and over-rides the more precise outline and uniform tone of modern tiles.

The revival of this branch of the ceramic art has given rise to a purer taste in all that concerns domestic decoration, and induced ideas of cleanliness unknown before.

The modern mode of making encaustic or inlaid tiles is first by modelling the design from a drawing on a thin film of clay on a plaster ground, or by incising the ornament on a block of clay or plaster, and then pouring over the model, plaster of Paris to form a mould. Moulds from a hard plaster or a carved wooden model are sometimes made in brass, and a metallic frame is often the boundary of the plaster mould. Metallic moulds for patterns which are to be much repeated are the best and most economical. The clay for the body of the tile is pressed into a mould by a small screw-press; and the mould produces the outer form of the tile, and the ornament on the surface, at the same turn of the screw. After the tile has been pressed, and removed from the mould, it is allowed to become tough in dryness, before the operation of filling in the indented ornamental surface takes place. When the tile is thus far dry, a thin mixture of white, buff, or coloured clay is carefully poured over the indented parts; if two or more colours are to be poured in, stops of clay, or coverings, are used to check the running of one colour into another, and the respective colours are thus filled in one after the other. After filling in, the tile is placed again to dry, and when very stiff, it is carefully scraped over with a thin piece of steel, and all the coloured clay lying unevenly on the surface is removed. The ornamental features are then seen in sharp outline, and the tile is thoroughly dried for firing. There is a disposition in some clays, when so treated, to round on the face in drying and burning; this is checked by placing a thin layer of clay of a different refractory character on the back of the tile when it is first formed, and piercing holes through this layer of clay, to admit of the free egress of steam and fixed air. The modern practice is to glaze such tiles as are required to have an enamelled surface, by a second firing, after burning them first in the biscuit state.

Without trespassing upon the subject of porcelain buttons (see Buttons, p. 559), it may here be mentioned that, in 1840, R. Prosser, of Birmingham, obtained a patent for the manufacture of buttons by reducing the material of porcelain to a dry powder, and subjecting it to strong pressure between steel dies; the powder, being compressed into about a fourth of its bulk, becomes a compact substance, and can be at once placed in a kiln and fired. Prosser disposed of part of his interest in this patent to Herbert Minton, who then made some very beautiful china buttons and studs. In 1841, Blashfield saw them and learnt how they were made, and conceived that the button-making process might be extended to the manufacture of tesseræ and small tiles for pavements. A correspondence ensued between Blashfield and Minton on this subject, and the latter made some experiments, and sent Blashfield some 1-in. cubes, having a blue colour on one face and a white body. The blue colour was crazed and cracked. Minton made further trials, and succeeded in producing some very good blue and some white tesseræ, $\frac{3}{8}$ in. thick and $\frac{7}{8}$ in. sq.; these Blashfield placed together in the form of a Greek fret on a drawing-board face downwards, and poured Roman cement over them, pressing some flat roofing-tiles into the cement, and thus formed them into a small slab. When the cement had set, the face of the mosaic was washed, and this first piece of Minton's mosaic work was exposed to the weather during the whole winter, and received no injury from the frost.

Prosser enlarged his patent to cover the making of tesseræ and tiles, and began to make machines for Minton's use in this way, and entered freely into Blashfield's views. The latter suggested sizes of tesseræ and tiles, and colours, and the importance of gilt and enamelled tesseræ, and gratuitously provided Minton with designs of mosaic pavements and tiles, and copies of those in Westminster Abbey, subsequently calling to his aid Owen Jones, H. Kendall, and Digby Wyatt, and commencing with them a series of publications of designs. In 1843, the process of manufacture was exhibited by Prosser and Blashfield at a meeting of the Royal Society, when the late Prince Consort took great interest in the making of the tesseræ, and desired an account of the whole subject to be sent to him.

Minton hesitated to order machines for forming tesseræ and tiles beyond the sizes of 1 in., ½ in., and ¼ in.; but Prosser made the necessary tools, and in 1844–1845, tiles of large size and various shapes, and slabs 3 ft. long, were fabricated. Michael Hollins, the present proprietor of the tile works, laboured most zealously from the first in the fabrication of the raw material and colours.

Having related something of the early history of this important improvement in the ceramic art, which has brought about such vast changes in architectural decoration, and which is making every day fresh strides, we will enter upon a description of the machine first employed to make tesseræ, and which, with a few modifications, is still used for tesseræ and small thin tiles, a more powerful machine and hydraulic presses being used for large and thick tiles, and other flat surfaces, and for making bricks from powdered clay. The preparation of the powdered material may be explained in a few words. For tesseræ, it frequently consists of alumina, silica, and baryta, mixed with some metallic oxide for colouring matter. The difference between the new process and the old is that the clay or earthy material for making the tesseræ, tiles, or other articles, instead of being used in a plastic state, is used in dry powder. The materials may be of the same character, and, up to a certain stage in their combination, they undergo a like preparation. For example, they are mixed with water, and ground by machinery, to thoroughly incorporate them, and, in a semi-liquid state, are passed through fine sieves, to remove all coarse particles; and when this is done, the clayey paste is partially dried by the heat of a slip-kiln, and made up into balls, which, when perfectly dry, are ground in a mill; and the dry ground material, for fine surfaces, is passed through sieves, to prevent the risk of any coarse particle or dirt getting into the articles which are to be moulded.

Tiles must be classified rather by the processes of their manufacture, than by the materials of which they are composed. Tiles may be made by the same process, and yet may present as great a difference in texture as fire-ware on the one hand and vitreous stone-ware on the other. The body most commonly used is that of ordinary white earthen-ware; but for coloured tiles, and for a backing to a surface of superior quality, mixtures of local marls and fire-clays are largely employed. There are two principal processes, which may be distinguished as the wet process and the dry process. By the former, tiles can be made by hand, or by mechanical pressure; by the latter, by mechanical pressure only. In making plain tiles by the wet process "bats" of plastic clay are prepared in the ordinary way by manual or mechanical "batting," and are either cut to any required dimensions, or are beaten into a metallic mould. Tiles made as described are burnt in saggers, and reburnt after dipping in white or coloured glazes. The backs of tiles, whilst still plastic, are always impressed with small holes or depressions, which may form a key for the cement when they are applied to walls or other surfaces. So-called "Palissy" and "majolica" tiles are made from plastic clay "bats," which have received a raised pattern on their surfaces from a depressed pattern sunk into the mould in which they have been pressed. After first burning, the Palissy tiles are dipped into transparent coloured glazes, and the majolica tiles into opaque enamel slips.

The dry process consists in consolidating clay powder by mechanical pressure. The clay powder, having been damped, is placed upon a metallic block of the size of the tile to be produced, surrounded by a movable collar, and is compressed by the descent of a plunger into the mould so formed. The pressure is communicated to the plunger by a vertical screw, and the momentum is obtained from a horizontal fly-wheel or weighted arm. The compressed powder is removed by means of a pedal, which lowers the collar or edge of the mould. The tiles thus produced may be either large or small, according to the power of the presses employed. Small tiles and tesseræ are made by girls in small hand-presses. The moulds can be so made that several tesseræ can be pressed at one motion. The compressed tiles are burnt for biscuit and glaze in the same manner as those made by the wet process. The compression of powder as a means of manufacture is not now limited to the production of tiles; at the present time, plates and gallipots are being made by an application of the same process. Coloured patterns may be inlaid in tiles by either process.

The colours employed are clays coloured naturally, or by the artificial admixture of the oxides of iron, nickel, manganese, or cobalt.

The wet process consists in forming a pattern in relief in plaster, and framing and backing it in a metallic support. Into the mould thus formed a thin bat of white plastic clay, backed with a clay of inferior quality, is pressed, and receives from the plaster mould a depressed pattern. A layer of white clay is then spread upon the common clay in order to counteract any contortion arising during firing from a disagreement between the common clay and the white clay on the face. The tile is heated until it can readily be removed from the mould. Into the depressed pattern on the surface, coloured clay slips are instilled from suitable vessels, and when the excess has been removed by scraping, the pattern is discovered.

The dry process is a further application of that already described. Upon the central block, a pattern is dusted with powdered clay through a thin metallic stencil-plate; the collar is then raised, and a layer of clay is inserted, and compressed by the descent of the plunger; a layer of inferior clay is next added and compressed; and finally a layer of the same clay as that used for the surface, the collar being raised to receive each fresh layer. The removal of the tile is facilitated by the depression of the collar. The same results may be obtained both for plain and inlaid tiles, by raising or depressing by a pedal a movable base working inside an immovable collar.

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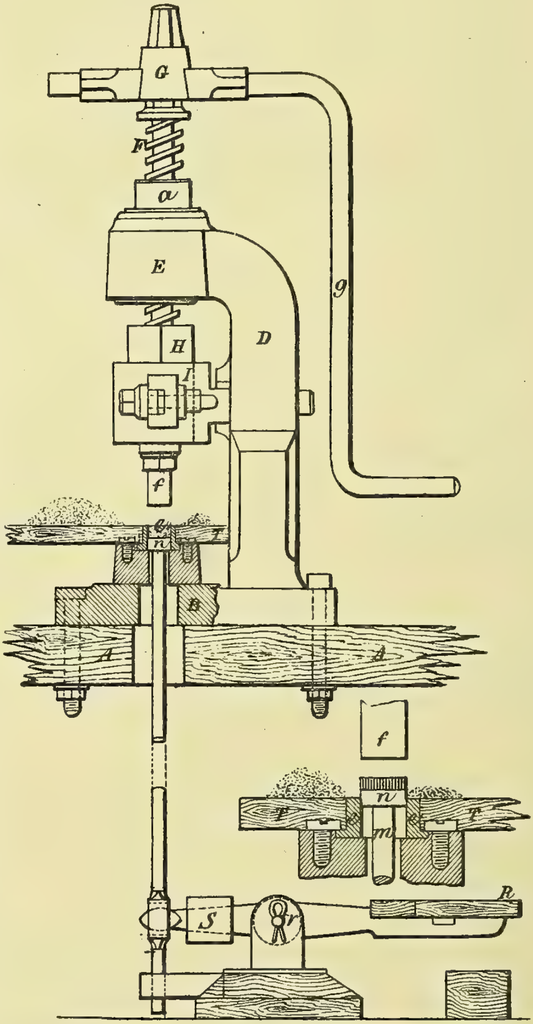

One of the earliest machines and moulds used for moulding articles of a small size in powdered clay is represented in Fig. 1160: A is the wooden bench on which the whole is fixed, the bench being sustained on legs standing on the floor; B D E, the frame, formed in one piece of cast-iron, the base B being fixed on the bench by screw-bolts, the upright standard D sustaining at its upper end the boss E, wherein the nut or box *a* is fixed for the reception of the vertical screw F; the screw F works through the box *a*, and has a handle G *g* *h* applied on the upper end of the screw; the handle is bent downwards at *g*, to bring the actual handle *h* to a suitable height for the person who works the machine; by pulling the handle *h* towards him, the screw F is turned round in its box *a*, and descends. The lower end of the screw F is connected with a square vertical slider H, which is fitted into a socket I, fixed to the upright part D of the frame, and the slider H is thus confined to move up or down with an exactly vertical motion, when it is actuated by the screw. Thus far, the machine is an ordinary screw-press, such as is commonly used for cutting and compressing metals for various purposes.

The tools with which the press is furnished consist of a hollow mould *e*, formed of steel, the interior cavity being the exact size of the article to be moulded. The mould is firmly fixed on the base B of the frame, so as to be exactly beneath the lower end of a piston or plug *f*, which is fastened to the lower end of the square slider H, and the plug *f* is adapted to descend into the hollow of the mould, when the slider H is forced downwards by action of the screw F, the plug *f* being exactly fitted to the interior of the mould. The bottom of the mould is a movable piece *n*, which is exactly fitted into the interior of the mould, but which lies at rest in the bottom of the mould during the operation of moulding; but afterwards, the movable bottom can be raised by pressing the foot upon one end R of a pedal-lever R S, the fulcrum of which is a centre-pin *r*, supported in a standard resting upon the floor; the end S of the lever operates on an upright rod *m*, which is attached at its upper end to the movable bottom of the mould. A small horizontal table T is fixed around the mould, and on that table, a quantity of powdered clay is laid in a heap in readiness for filling the mould.

The operation is very simple; the operator holding the handle *h* with his right hand, puts it back from him, so as to turn back the screw F, and raise the slider H and plug *f* quite out of the mould *e*, and clear above the orifice of the mould, as shown in Fig. 1160. Then, with a bone spatula held in the left hand, a small quantity of the powder is moved laterally from the heap, along the surface of the table T, towards the mould *e*, and gathered into the hollow of the mould with a quiet motion, so as to fill that hollow very completely; and by scraping the spatula evenly across the top of the mould, the superflous powder will be removed, leaving the hollow cavity of the mould exactly filled with the powder in a loose state. The handle *h* being drawn forwards, with a gentle movement of the right hand, it turns the screw F, so as to bring down the slider H and plug *f* into the mould upon the loose powder, and begins to press the powder with a gentle motion, without any jerk, in order to allow the air contained in the loose powder to make its escape; but the pressure, after having been commenced gradually, is continued and augmented to a great force, by pulling the handle strongly at the last, so as to compress the earthy material upon the bottom *n* of the mould, into about one-third of the space it had occupied when it was in a state of loose powder.

The handle *h* is put back again, so as to turn the screw F, and raise the slider H and plug *f* until the latter is drawn up out of the mould *e*, and clear above the orifice of the mould; and immediately afterwards, by pressure of the foot upon the pedal R of the pedal-lever R S, and by action of the upright rod *m*, the movable bottom *n* of the mould is raised in the mould *e*, so as to elevate the compressed material which is resting upon the bottom *n*, and carry it upwards out of the mould *e*, and above the orifice of the mould, when the compressed material can be removed by the finger and thumb. The compressed material so withdrawn is a solid body, retaining the exact shape and size of the interior cavity of the mould, and possessing sufficient coherence to enable it to endure as much handling as is requisite for putting a number of them into an earthenware case or pan, called a sagger, in which they are to be enclosed, according to the usual practice of potters, in preparation for putting them into the potter's kiln for firing.

After the firing, the articles made are in what is called the "biscuit" state, and such as are required to be glazed are dipped into the fluid glazing-compound, and are again fired. All small pieces made by this dry-powder process may be glazed at the first fire by introducing a glazing-composition within the saggers. The materials forming small articles may be so prepared that the articles become partially vitrefied by the heat of the kiln.

All articles made from powdered clay contract less than those made from wet clay, and are more even on the surface; and time is saved by using a dry instead of a wet material. Articles of the same form are more uniform in size, and join and fit at edges and angles with greater exactness.

Encaustic tiles, as well as plain flat tiles, are made from dry powder. A thin piece of metal, with the pattern cut out, and fitting exactly over the indents pressed in the tile, is laid carefully over it, and then some coloured powder is spread over the metallic pattern, and pressed by a screw into the indented parts. The thin metallic plate is removed, and the superfluous clay lying about the surface of the tile is scraped off with a piece of steel, to fully bring out the design, as is done in making these tiles in the wet state. Tiles may be made in this way of half the thickness of those formerly made from wet clay, and of every geometrical form. It would have been impracticable to produce tiles at small cost for covering walls, as is now commonly done, by the old way of working.

Tiles only ½ in. thick of special forms are made for paintings, and are laid together; and figures of life size are drawn on them in a free spirited manner, and painted. These tiles are then fired again to fix the colours on the glaze. Sometimes colours are printed or painted on the biscuit tile, and it is then fired to harden on the colour, and is afterwards glazed. Every kind of flat ornament in bas-relief can be pressed in powdered clay and enamelled. There are fine examples of mosaic and tile flooring, and of tile wall decoration, in the South Kensington Museum, suggestive of the use of this art in many ways; and in several of the new restaurants and hotels, are special examples of its use.

In this country, where we have every variety of clay, and all the other materials necessary to make semi-vitreous forms of all colours, fitted for the use of the architect and civil engineer, and known to resist the severities of this climate better than granite, marble, or stone, it is remarkable that greater attention is not given to the use of architectural pottery. By the aid of machinery, are produced bricks, of good shape and with true surface; also plain moulded bricks, for string courses and cornices; and from plaster moulds, foliated mouldings and enrichments to combine with such bricks; and as the description of the new mode of making flat surfaces from dry powder, shows that mosaic and inlaid decoration, either in biscuit or enamelled ware, can be made to aid decoration at moderate cost, it is to be hoped that the example set by a few architects who have freely used these materials may be generally followed, and that the costly material, stone, which soon becomes dingy, and gives way to frost and the atmosphere of large towns, will be less in fashion.

Wares rendered Translucent by the fusion of an Incorporated Felspathic Glass.—The origin of the manufacture, in England and on the Continent, of every sort of translucent ware, was the wish to produce a facsimile of Chinese porcelain. The desired translucency has been attained with greater or less success in a variety of ways. The *pâte tendre* of Sèvres was in reality a glass, rendered sufficiently plastic by artificial admixture to be manipulated as clay, and fired at a temperature high enough to fuse the glass, but not so high as to injure the form of the ware. The resultant ware was so fragile, and the difficulties of manipulating the mixture, of supporting the ware during firing, and of adjusting the temperature of the kilns, were so great, that the manufacture of *pâte tendre* was gladly abandoned on the discovery of kaolin at St. Yrieix. English china is rendered translucent by the addition to a pure plastic clay of a considerable proportion of glass-forming materials, but the proportion is so regulated that, although the ware does not require excessive heat for its firing, its plasticity is sufficient to facilitate manipulation; moreover, the balance of fusibility and plasticity is so adjusted as to allow the introduction of sufficient calcic phosphate to reduce the shrinkage of the ware to a minimum, and at the same time greatly to add to its brilliancy. English china is easily worked, easily fired, and easily decorated. The hard porcelains of Berlin, Sèvres, and other European manufactories, resemble true Chinese porcelain in being produced from purely granitic materials. They differ from English china in being more difficult to manipulate, in requiring a higher temperature for firing, and in being less susceptible of receiving colour and other forms of decoration. They are superior, however, in their power of resisting corrosion, and of withstanding extreme changes of temperature.

The physical structure of translucent wares may be described as that of a transparent glass, holding opaque infusible particles of kaolin or other substances in suspension. Microscopic examination of a thin plate of hard porcelain reveals opaque rods, granules, and fragments of quartz, and spherical bubbles, bound together by a vitreous cement. The want of transparency is caused by the repeated reflection and refraction of light by these obstructive particles. The chemical nature of the different translucent wares is best illustrated by reference to the table of analyses (p. 1558). The proportions of alkalies, and of calcic, ferric, and magnesic oxides reckoned together are, approximately, in English china, 12; in Parian, 8; in Sèvres, 8; in Chinese, 7; and in Berlin and Japanese, 4. Of the alkaline constituents of Japanese porcelain, the sodic oxide is in excess; whereas in the case of Chinese porcelain, potassic oxide preponderates.

The raw materials used in the manufacture of hard porcelains are kaolin and felspar, or a felspathic mineral. The felspathic constituent or *petuntze* of the Chinese potters is potassium felspar, the orthoclase or adularia of mineralogists. The general processes of manufacture and manipulation in China and Japan are similar to those employed in Europe, although of a rougher character. Homogeneity is procured in the prepared mixture by repeated treading, and the mixture is always stored for a considerable time before being worked into ware. Hand-driven throwing-wheels are employed, and dried clay is used for moulds in the place of plaster of Paris. The glaze, which is made of felspar and lime, requires an intense heat for its fusion. There are few metallic oxides, except that of cobalt, which can withstand the requisite temperature, and it is therefore necessary to apply the less stable colours in the form of enamels upon the glaze, and to fuse them at a lower heat. The wares are generally subjected to a moderate fire before the application of the under-glaze colour and the glaze, although it is possible to fire at one time for biscuit, under-glaze colour, and glaze.

Sèvres hard Porcelain.—The raw materials used at Sèvres are kaolin from St. Yrieix, and chalk. The kaolin in its natural condition contains a considerable but varying proportion of felspathic sand. If the raw kaolin be exposed to an intense heat, it fuses to an opaline glass. In order to regulate the fusibility of the resultant ware, it is necessary first to separate the felspathic sand from the kaolin, and then to remix it in proper proportions. Separation is effected by agitating the raw kaolin with water in a suitable receptacle, allowing the heavy felspathic material to deposit, and drawing off the suspended kaolin into a second or series of receptacles, where it is gradually deposited, and from which the water, together with the floating and soluble impurities, may be run off from above. The felspathic sand is collected and ground with water in a mill with stone runners. The chalk is also ground, and the kaolin, felspar, and chalk, after passing a succession of sieves, are mixed together by measure in a liquid condition. The liquid mixture is consolidated partly by the expression of the water through a filtering medium of prepared linen, and partly by absorption of the water by plaster of Paris. The paste so formed is kneaded and beaten upon slabs of plaster of Paris, moulded into lumps, and stored in cellars for future use. The average proportion in which the three ingredients are mixed is: kaolin, 48; felspathic sand, 48; and chalk, 40. The comparatively large proportion of felspar and lime renders the mass deficient in plasticity. To partially counteract this defect, parings of unburnt ware are mixed with the dried and pulverized paste. This mixture is again carefully kneaded, and incorporated with sufficient water to produce the amount of plasticity requisite for manipulation. The processes of throwing, pressing, moulding, and casting, are similar to those already described, although modified in certain respects to suit the nature of the mixture. The mixture is less plastic, and more liable to defects from deficient homogeneity, than is the case with the mixture for English earthen-ware and china. In throwing, it is customary to subject the mass of paste, after being kneaded, to a preliminary moulding on the wheel, in order to ensure the regular aggregation of the constituent particles; it is also usual to allow the substance of the article in the rough greatly to exceed that of the finished pattern, provided the internal diameter remains the same, so that the exterior may be pared away by turning, and signs of unequal pressure be removed. The paste is prepared for pressing and moulding, by the passage over it of a wooden roller running upon guides; and the bat of paste is raised from the bed of plaster of Paris upon which it has been rolled, by means of an underlying film of skin or other material. In casting, the liquid paste is allowed to remain in the mould for a considerable time.

After manipulation, the wares are gradually dried, preparatory to burning. The ovens employed at Sèvres are each divided into two kilns, an upper kiln for burning biscuit ware, and a lower kiln for burning the ware which has been dipped in glaze. The biscuit- and glaze-kilns are separated by a perforated floor, through which, the surplus heat from the glaze-kiln passes into the kiln above. The heat and draught of the kiln are very intense; there is little smoke, and the ash is entirely dissipated. The fuel principally used is wood, and every precaution is taken to prevent dust.

The wares, whether for the biscuit- or glaze-kiln, are placed in saggers, and rest within the saggers upon flat ground slabs, made of a refractory clay dusted over with flint or fire-clay slip, and bedded evenly in sand. The saggers are built up by plumb line, with every precaution to secure the wares resting perpendicularly. The firing is regulated by the removal at stated intervals of small test-pieces of both biscuit and glazed ware, of the same composition as that used throughout the kiln, which have been previously placed in saggers from which they can be readily withdrawn from the outside. There are three stages in the management of the kiln: the gradual heating for the removal of moisture held by the body or glaze; the actual baking of the body, and fusion of the glaze; and the annealing of the glass in the body of the ware, as well as in the glaze. The firing may last 30–45 hours, and the kilns may remain closed after the firing, to allow of the gradual cooling of the ware, for a period of 5–8 days. The entire shrinkage of hard porcelain amounts to about 17 per cent.

Glaze.—The material used for the glaze is a natural mixture of felspar and quartz, and is known as pegmatite. Its average composition is silica, 74·3; alumina, 18·3; potassic oxide, 6·5; calcic oxide, 0·4; magnesic oxide, 0·2; water, 0·3; and it may be approximately represented by the formula $2(Al_2O_3,3SiO_2)+K_2O,3SiO_2$. It is therefore an ordinary glass, to which a second equivalent of aluminic silicate has been added, and the transparency of which is destroyed by the excess of infusible material.

Each fresh supply of pegmatite is tested in order to ensure a constant result. For use, the pegmatite is first crushed under vertical grinding-wheels turning upon a revolving base. It is then ground with water in a mill with stone runners, and when reduced to a sufficient degree of fineness, is drawn off, sifted, agitated in the presence of magnets, in order to remove particles of iron, passed into a receptacle, and maintained in suspension by constant agitation.

During the long process of grinding with water, great care must be taken to prevent a sudden precipitation of the material, either through the slackening or sudden stoppage of the stones. The tendency to precipitation may be retarded by mixing a small quantity of acetic acid with the water. The various mills at the Sèvres works are moved by water-power. Into the suspended pegmatite, the biscuit ware is dipped, care being taken that no part of one piece remains in the glaze longer than another, and that the thick wares shall be dipped in a thin glaze, and the thin in a thick. The parts of ware which have been held in the dipper's hand are retouched with a brush dipped in the glaze. The wares are replaced in saggers, and the saggers are placed in the lower division of the oven, the heat of which is more intense than in the biscuit-kiln. The entire absence of lead renders the glaze when fused exceedingly hard and durable; it is bluish in tint, and cold to handle. The grey tint of the body and glaze is due to the reducing action of the atmosphere of the kiln. The glaze is transparent, and rather more fusible than the body, but becomes thoroughly incorporated with it, and, from its similarity of composition, expands and contracts uniformly with the paste. The bases of ware when removed from the saggers are rubbed smooth with sandstone. Owing to the difficulty of manipulating the paste, it is customary to build up elaborate vases from distinct pieces, which are joined together by metallic fittings; this especially applies to feet and handles.

Parian and Belleek.—The nearest British representatives of true porcelain are Parian and Belleek. The materials generally used for Parian are kaolin, felspar, and small quantities of Cornish stone and ball-clay: the analysis of an average sample of Parian gives—silica, 54·8; alumina, 36·21; alkalies, iron, and other ingredients, 8·8. In some cases, the composition and preparation of Parian approaches closely to that formerly employed at Sèvres in the production of the *pâte tendre.* A glass is first formed by the fusion of a mixture of sand, felspar, Cornish stone, and potassic carbonate; this is run into water whilst still hot, broken up by the action of the water, and ground with water in a mill with stone runners. One part of the glass is mixed with about three parts of ground felspar and three parts of kaolin. A hard Parian may be made from a mixture composed of 60 parts felspar, 30 kaolin or china-clay, and 10 ball-clay. The Parian mixture is used in the liquid state, and the ware is fashioned by the absorption of the water from the mixture, and the consequent deposition of the paste upon the inner surface of dry plaster of Paris moulds. Vases and statuettes of the greatest delicacy may be produced by these means. The contraction of Parian in the process of solidification by heat is greater than in any other ware, and amounts to $\frac{1}{5}$–$\frac{1}{3}$ of the entire mass. It is worked in a state of perfect liquidity, and is rendered quite vitreous by fusion. The shrinkage is greater in the height of the ware than in the width, owing to the influence of gravitation. In making models for the moulds in which the wares are cast, provision must be made to counteract the inequality of contraction, and to bring the contraction to a common centre.

In reproducing a human figure, or group of figures, every limb is cast singly in a separate mould, and the whole is built up piece by piece, and cemented together in the green state by the interposition of liquid slip. Each mould is in two pieces, fitting closely together, and fixed by projections on one side protruding into corresponding depressions on the other. An opening is left in the middle of the upper part of the junction of the two sides, through which the liquid mixture can be instilled from a suitable vessel. The cavity of the united mould is filled and refilled as the water is absorbed, and until a sufficient thickness of paste has been deposited. So soon as the paste has become solid by absorption, the moulds readily deliver. The wares are burnt in specially-prepared saggers, and are supported in every direction by carefully arranged props made of refractory clay. The drapery of figures may be reproduced by spreading lace, or some fine textile, upon a slab of plaster, covering it with a layer of liquid paste, wrapping as required upon the figure, and simultaneously solidifying the paste and destroying the fabric by the fire to which the figure is exposed.

The creamy tint of English Parian is due to the formation in the body of the ware of a glass fused in an oxidizing atmosphere, and tinted by the ferric oxide naturally incorporated with the constituent materials. Foreign Parian has generally a greyish tint, owing to the reductive atmosphere of the kilns in which it is fired. The name of Belleek is commonly given to a species of glazed and lustred Parian, but the genuine ware is made from a mixture of kaolin and felspar artificially prepared from red orthoclase granite, and which has the property of assuming when fired a natural enamel or egg-shell film.

Artificial Porous Ware.—Porous ware is required for several purposes, especially for water-coolers and the inner cells of galvanic batteries. The principle upon which this manufacture is based is the introduction into the clay mixture of a proportion of some organic substance which will be destroyed by heat. The substance generally used is saw-dust. As the battery-cells are required to be exceedingly regular and thin, they are formed by the process of absorption or "casting" which has been already described (compare Parian). A clay containing an appreciable quantity of calcic oxide is unsuited for the manufacture of battery-cells. The moulds employed in the process of casting have constantly to be replaced, as they are subject to damage, by reason of the repeated absorption and evaporation of large quantities of moisture.

English China.—English china is generally of a dead or creamy-white colour, is translucent, and is apparently less cold to the touch than hard porcelain. The glaze is soft, and the ware will not resist extreme variations of temperature. The mixture for English china is manipulated and fired with greater facility and certainty than would be possible with simple granitic materials, and the resultant ware is adapted to a greater range and brilliancy of decoration than is applicable to a harder and less manageable composition. The materials employed are China-clay, or kaolin, ball-clay, Cornish stone, flint, and calcic phosphate, together with, in some cases, a small proportion of steatite, which consists of 63 silica, 33 magnesic oxide, and 4 water. The translucency of English china is due to the fusion of the felspar contained in the Cornish stone. The calcic phosphate performs many useful functions. In addition to reducing shrinkage, and enhancing the whiteness of the ware, it enables it by its infusibility to stand the fire requisite for the vitrification of the felspar, and adds lightness without materially affecting translucency. An analysis of a sample of Worcester china gives: silica, 38·88; alumina, 21·48; calcic oxide, 10·06; sodic and potassic oxides, 2·14; calcic phosphate, 26·44. Every manufactory has a different mixture for china, but the following may be taken as an average specimen: kaolin, 31·00; Cornish stone, 26·00; calcic phosphate, 40·50; flint, 2·50. The glaze is composed of a fused glass, ground and added to a mixture of Cornish stone, or felspar and plumbic carbonate. A glaze for a body composed as described might consist of 60 parts of a glass formed of—Cornish stone, 48; borax, 24; calcic carbonate, 20; potassic nitrate, 4; and sand, 4; added to plumbic carbonate, 16; and Cornish stone, 24.

In selecting materials both for the body and the glaze, the greatest attention is paid to their purity, and freedom from iron.

The processes employed in preparing the materials and manipulating the paste are similar to those already described under the head of Earthen-ware (p. 1573), but carried out on a smaller scale. The plastic clays are broken up by agitation with water, and the Cornish stone, calcic phosphate, and flint are ground with water under stone runners. The grinding-pans measure 10 ft. in diameter and 3 ft. in depth, and are paved with small blocks of chert-stone. The different materials, suspended in water, are sifted, and run by measure into a large receptacle, in which they are mixed and kept in agitation by revolving arms, carrying magnets, which attract and withdraw from the mixture any particles of metallic iron that may be present. The mixture is thence pumped into a filter-press, which is generally of a lighter and simpler construction than that used for earthen-ware. Pressure is applied by a hand pump, and the sacks are connected by central fittings, which, when united, form a single central tube through the entire series of sacks. When the paste is taken from the sacks, it is subjected to repeated beating, turning, and kneading, before it is considered to be in a proper working condition.

Another method of procedure is to dry the liquid materials separately by evaporation on a long shallow stone reservoir heated from beneath, and to mix the separate ingredients in the dry state by weight, to remix them with water, then to pump the liquid mixture first through a series of sieves, next through a series of stationary electro-magnets, and finally into the filter-press. The ingredients of the glass, which forms the largest constituent of the glaze, are mixed and introduced into the furnace represented in Fig. 1152. When melted, it is run from the furnace into water, broken up, dried, ground, and mixed by weight with the plumbic carbonate and ground Cornish stone. The mixture is then ground with water in a mill similar to, but smaller than, that used for grinding the hard ingredients of the body, until such time as the liquid glaze will pass a silk lawn containing 4000 meshes in 1 sq. in. The ovens and saggers are similar to those used for earthen-ware. The wares are bedded in the saggers in calcined flint, and the saggers are built up in airtight columns by the insertion of rolls of moist clay. The kiln for biscuit-firing takes 40–50 hours to fire, and about 48 hours to cool; the glaze-kiln takes 15–20 hours to fire, and about 36 hours to cool, and to allow the glaze to become annealed.

Decorative Processes.—The decorative effect of pottery is due to form, surface, or colour. Decorative form may be due to the taste and manual skill of the thrower, or, if the ware be moulded, pressed, or cast, it may originate with the art of the designer of the model for the mould. Ware, after receiving its outline from the thrower, and whilst still retaining plasticity, may have its form compressed, or indented, and its edges waved or crimped by the fingers, and according to the fancy of the artist. Ware may also be built up of detached pieces, as in the case of fine basket-work, and of imitation flowers. In the former, threads of clay, expressed through a stencil fixed in the base of a cylindrical screw-press, are twisted and cemented together, laid upon a plaster block of the shape which the interior of the basket-ware is intended to possess, and hardened by burning; in the latter, each petal is made separately by hand, and cemented together by liquid slip. The mouths of vessels may be artistically shaped by the insertion of "forms" made of burnt stone-ware or china.

The colour in the body of a ware may be natural or artificial, and may be mechanically or chemically combined. It is due to the presence of a metallic oxide, and the colour may either be the actual tint of the anhydrous oxide, or the tint which a glass assumes when fused with the oxide. The red of terra-cotta is caused by the presence in the natural clay of ferric oxide; and the buff and paler tints, by a smaller proportion, amounting to 1–3 per cent., of the same oxide, or by a larger proportion intermixed with lime or magnesia. The tint of ivory and cream-coloured ware is due to a glass coloured yellow by a minute trace of ferric oxide, and intimately mixed throughout the body. The mixtures for cream-colour and ivory are respectively the same as those used for earthen-ware and china, with the difference that clays are used containing naturally a slightly higher proportion of ferric oxide, and that sand is sometimes substituted for flint.

In order to facilitate the colouring of stone-ware by the presence of artificially coloured glass, as for instance in making a blue ware by the addition of cobaltic oxide, it is necessary to add Cornish stone to the clay, so as to render the body vitreous, and to supply a flux for the colouring oxide. Wedgwood's fine "jasper" ware is an artificial mixture of the same character, but containing a large proportion of baric sulphate. This substance serves the double purpose of resisting fusion, and of reflecting any colour that may be incorporated in the body of the ware. An average mixture is, baric sulphate, 57·1; baric carbonate, 4·8; flint, 9·5; clay, 28·6. The ware is unglazed, has a crystalline surface, is vitreous throughout, and may be coloured in the same manner as a glass. The sage-colour is due to chromic and cobaltic oxides; the drab, to nickel oxide; and the dove-colour, to cobaltic and manganic oxides. Stone-ware may be tinted by mechanical mixture with certain oxides. Thus ferric oxide gives a red, brown, or chocolate; manganic oxide, a black; and uranic oxide, a yellow. Differently coloured clays may be so kneaded and worked together as to present a good imitation of the grain and colours of marble. The costly Henri-Deux ware may be reproduced by inlaying coloured clays in patterns, stamped or engraved in separate bats of plastic clay, adjusting the separate bats in a mould, and uniting them by a common backing of clay, so that they are made to combine, and assume the form of the mould. The body is generally white; the inlaid ornament, brown and black; and the glaze, a warm cream-colour.

A decorative surface may be produced by impression, incision, or application. Impressed decoration may be transferred from the surface of a mould, or may be directly produced by a stamp or seal, or by a pattern cut in relief upon the edge of a small revolving wheel; by the repetition of the impression of a stamp, the effect of a diapered background may be obtained. A moulded pattern may be cut through with a knife, so as to imitate coarse basket-ware; and the delicate tracery of perforated ware may be produced in the same way, but with finer implements and greater skill. Lattice-work, executed in a similar manner, may be applied over depressions, or upon the surface of vessels which still retain their plasticity. A coloured clay is sometimes introduced into moulded depressions, and the surplus is removed on the lathe.

After a vessel has been thrown, patterns may be scratched upon it with a graver; if the clay be still moist, a ridge will be left by the tool on each side of the incision; the ridge, however, will not be formed if the clay be already dry. If colour be afterwards applied, the ridge, when present, forms an outline to the colour. Rings may be left upon the surface of ware by the thrower, and may be carved by the artist. Etching and carving as described are generally applied to fine stoneware. This ware may also be decorated by the following processes:—By dipping a dark ware in a light-coloured clay slip, and etching through the latter so as to disclose the dark background; by modelling the borders of patterns out of strips of clay laid upon the vessel whilst still plastic; by painting upon a dark body with light-coloured clay pigments, in certain cases, using a vitrifiable pigment, so as to become semi-transparent, and to disclose the background; by applying to the surface of ware, dots, rosettes, gems, or patterns, previously moulded in plaster moulds, or modelled ornaments in the form of dragons or faces. The decoration known as *pâte sur pâte*, and generally applied upon china or porcelain, and covered with glaze, is produced by modelling in a porcelainous paste spread upon the surface of the ware. The surface of the ware is generally of a dull-grey or green colour, applied to the ware by dipping in a coloured slip or glaze. The colour shows through the thinner parts of the sculptured ornament, the paste employed being of a semi-vitreous character. The bas-reliefs applied to Wedgwood's jasper ware are formed in moulds, and are made to adhere to the unbaked ware, by means of liquid slip. The ware, if it be not already coloured in its substance, is generally dipped in a coloured slip, before the application of the bas-reliefs. Certain wares are decorated with flowers and delicate sprays of foliage, to the manufacture of which, reference has already been made.

The glaze is a simple form of applied decoration. It is, as has already been stated, a glass built up of two or more silicates. The normal felspathic glaze consists of sodic or potassic and aluminic silicates; salt glaze, of sodic and aluminic silicates; lead glazes are mixtures of plumbic with aluminic silicate, and small quantities of sodic and potassic silicates. There are also glazes containing zincic silicate, and ferric silicate, and, in some cases, one silicate is replaced by a borate. Glazes may be rendered white and opaque by the addition of an infusible excess of stannic and arsenic oxides, and may be coloured by metallic oxides, in the same manner as glasses. Glazes are applied by dipping, and by volatilization. The difficulty in preparing a glaze is the regulation of the mixture, so that the contraction of the glaze after fusion shall not be unequal to that of the body to which it is applied.

The well-known decorative effect of "crackle-glaze" is obtained by an adjusted disagreement between the body and the glaze. If the disagreement be allowed to go too far, the glaze chips away from the body. The requirements of a glaze are (1) agreement with body, (2) power of resisting solution and corrosion, (3) purity of colour, (4) power of developing applied colours. The felspathic and sodic silicate glazes are the most durable; the plumbic silicate glaze is liable to gradual decay, which is indicated by the appearance of a beautiful iridescent film. "Smears" and "flows" are glazes applied by volatilization. In the former process, the saggers are washed inside with a mixture of one or more of the following substances: salt, red-lead or litharge, potassic nitrate, potassic carbonate, and china stone. The ware, generally fine stone-ware, is exposed in these saggers, and receives a gloss by the deposition and combination of the volatilized mixture. The object of the use of "flows" is to soften or blur the outline of under-glaze painting or printing. Ammonic chloride, alum, and chalk, together with one or more of the materials used for "smears," are placed in small biscuit-cups in the saggers, together with the ware. The glass which is formed by the deposition of the mixture on the ware partially dissolves the colouring oxide, and softens the general effect. Plumbic silicate glazes are coloured by metallic oxides, and are used for colouring ware. In this way, imitation "crown" ware is often manufactured. A mottled or marbled surface is sometimes produced on ware by instilling differently coloured glazes from a vessel containing several chambers communicating with a composite neck. Opaque glazes or enamels are used to conceal a coloured body. Majolica is generally made of common fire-clay or marl, and is coated with opaque white enamels, upon which, whilst still moist, coloured enamel decoration is applied. Limoges ware is a clay body decorated by the aid of coloured enamels.

In Cloissonné ware, the outline is marked out by metallic threads soldered to a metallic body, and the interstices are filled up with enamels. Imitation Cloissonné is produced by painting on a white clay body with coloured enamels, or by forming a raised outline by painting with a mixture of iron and copper dust, hardening the same by fire, and filling in with colour. Palissy ware has a white or coloured body, covered with transparent coloured glazes. Bristol ware is coloured by coloured felspathic glazes. A curious lustrous or glistening effect may be caused by applying coarsely-powdered mica to the surface of ware. Genuine lustre or iridescence is produced by the irregularity of a glazed surface, caused either by decay, or by the adhesion of an almost imperceptible metallic film. Bismuth, gold, silver, copper, zinc, iron, and platinum are used for this purpose. The metallic salt is generally mixed with some strong reducing agent, and applied to the ware as a paint. The ware is then fired in a reducing atmosphere, the salt is reduced, and the metal is fixed upon the glaze of the ware by heat.

For Brianchon's lustre, which is similar to that used at Belleek and Worcester, a mixture is used of bismuth nitrate, resin, and essence of lavender. If ferric or uranic nitrate be added to this mixture, the glaze of the ware will be tinted by the ferric or uranic oxide, and the effect of the lustre will be heightened. Instead of applying the reducing agent together with the metallic salt, a reducing vapour may be directed upon a pigment rich in copper, silver, or other metals, with similar results. The red lustre of Gubbio ware is due to the action of smoke upon cupreous oxide; it is usually applied to a coloured body. Gilding and silvering are performed by fixing metallic gold and platinum upon glazed ware by partially fusing the glaze in small muffles or kilns adapted to the purpose. The metals may be used in leaf, as amalgams, in powder, or as precipitates from solutions. When used as an amalgam or in powder, a small quantity of flux is added.

Gold may be precipitated from solution by ferrous sulphate; the precipitate, after washing and drying, is mixed with bismuth oxide, and mixed as a pigment with thickened oil of turpentine. Platinum sponge may be similarly treated. A bright silver may be obtained by using as a pigment a mixture of platinic chloride and essence of lavender. The gold powder and amalgams require prolonged and careful grinding before they are fitted for use as pigments.

The metal, after firing, is generally dull, and if a bright gold is needed, it must be burnished by rubbing over with an agate or bloodstone. "Chasing" is marking with a burnisher a bright pattern upon a dull unburnished ground. The gold pigment may be applied over raised bosses of paste, or over depressed patterns eaten into the glaze by hydrofluoric acid. Patterns may be painted with the brush, and lines may be accurately described upon the edge or sides of ware by applying the brush, and causing the vessel to turn upon the operator's hand, or upon a horizontally revolving wheel. Patterns may also be stencilled on the ware with charcoal, and gilded over.

By mixing gold with silver in various proportions, and using the mixtures as pigments, a large number of tinted golds and bronzes may be obtained. Coloured decoration upon the surface of ware is produced by metallic oxides dissolved in or covered by the glaze, or by the application of opaque coloured glasses. Metallic oxides applied on the body of ware and under the glaze, as well as those mixed with the glaze, obtain the glass necessary for their development from the glaze. Metallic oxides applied on the glaze are used in the form of coloured glasses or enamels. The latter may always be detected by the touch, as they are raised above the level of the glaze. Colours produced by certain oxides are developed by special media, and certain colours are able to withstand a much higher temperature than others. To the latter class, belong the oxides of cobalt, chromium, iron, titanium, and uranium; these are adapted to English underglaze decoration; but the blue produced by cobaltic oxide is the only colour able to resist the intense heat required to fuse the glaze of Oriental and Continental hard porcelains.

Zincic oxide tends to brighten a large number of colours; others cannot be developed without the addition of stannic or sodic oxides; and others, especially the pinks produced by gold, deteriorate in the presence of plumbic oxide. The subjoined oxides when mixed with a glass give the following results:—Ferric oxide, yellow; ferrous oxide, green; manganic oxide with sodic oxide, violet, passing to grey and black; chromic oxide, yellow; a trace of chromic oxide with stannic oxide, pink; pink, crimson, brown, black, and green are obtained for underglaze printing colours from various combinations of chromic oxides; all kinds of overglaze greens, and some yellows, are due to the same oxide; cobaltic oxide, blue, deepening to black, and brightened by zincic oxide, but injured by the presence of manganese or nickel as impurities; cupric oxide with sodic oxide, turquoise-blue, passing to green; cupreous oxide, red; auric oxide with stannic oxide, pink to purple; uranic oxide, yellow to orange; titanic oxide, yellow; antimonic oxide, yellow; plumbic oxide, pale-yellow; iridic oxide, black or opacity. All intermediate tints may be obtained by mixing the oxides.

Certain colours cannot withstand a high temperature, and other colours vary in tint with variations of temperature. Upon this fact, pyrometrical tests for burning-in coloured glasses and enamels are based. The heat of a muffle is ascertained by withdrawing from time to time a piece of china or porcelain marked with a glaze containing auric and stannic oxides. As the temperature rises, the tint changes from brown to brick-red, from brick-red to rose, from rose to purple, from purple to violet, from violet to pale-rose, and from pale-rose to a colourless stain. Wedgwood's pyrometer, which has been sometimes used for the same purpose, is based upon the regular contraction under the influence of heat of an unburnt clay mixture of known composition. Small cylinders of this clay mixture are expressed through a gauge, and after being dried, but before being placed in the kiln or muffle, are tested in a gradually tapering groove cut in copper or gunmetal. They are then placed in the muffle, and withdrawn when the temperature is to be determined. The temperature can be roughly estimated according to the position in the groove to which the contracted cylinder can be advanced, by reference to a scale determined by previous experiment.

Underglaze coloured decoration may be placed upon biscuit ware by the brush, or by a process of transfer printing. Only those oxides can be used for producing colour which are sufficiently stable to resist the heat of the glaze-kiln, namely those of chromium and cobalt. The pattern to be transferred is etched upon copper plates with steel gravers. When in use, the plates are kept warm by placing them on the top of a covered stove heated by steam, gas, or coal. The printing medium containing the colouring oxide is made up of a mixture of thickened linseed-oil, rosin, tar, and other ingredients, and is kept in a semi-liquid glutinous condition by exposure to heat. The ink is applied to the plate, and all the superfluity is dexterously removed by a scraper. A sheet of unsized linen tissue-paper, saturated with soft soap and well damped, is next spread upon the plate, and passed through the printing-machine.

The printing-machine, Fig. 1161, consists of an iron framework supporting two rollers, the upper one of which is partly wrapped with thick flannel. Between the two rollers, is a planed iron table, upon which, the copper plate is placed. By depressing the handle, the upper roller revolves, and causes the table to carry the plate between the two rollers. The resultant pressure transfers the ink from the copper plate to the paper. The printed paper is removed from the plate, and the margins are cut away. The paper pattern is applied to the absorptive surface of the biscuit ware, and is rubbed over with a roll of flannel. The ware is then placed in water, the paper is removed, and the pattern is found to be accurately printed. The printed ware is now dried, placed upon shelves in a kiln, and exposed to a red heat, in order to burn off the oily ingredients with which the metallic oxide was mixed. If the oily matter be not removed, the parts of the ware so covered will be non-absorptive, and unable to receive the glaze. After the ware has been gradually cooled, it is ready for dipping in the liquid glaze. By this process, outlines to be filled in by hand-painting, or patterns in one tint, can be printed. In order to print different shades of colour, a process known as "block-printing" must be adopted. In printing a leaf by this process, the different colours of the shadow, fibre, and ground are successively applied by separate plates upon the same paper, but care is taken that no two colours shall overlap. The pattern is transferred to the ware in the same manner as already described. The highest form of coloured decoration upon the glaze is hand-painting. Transparent coloured glasses and opaque enamels are used by the artist in the same manner as ordinary pigments, with the exception

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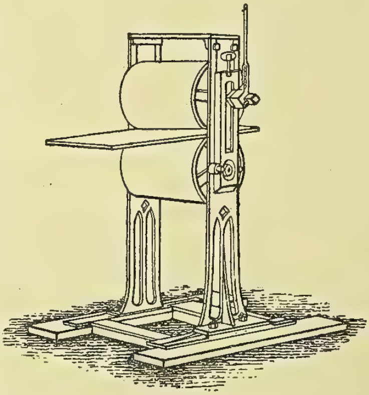

that all have to be fired by heat, and allowance must be made for the changes in tint which the firing may produce. So great skill has lately been devoted to the preparation of these colours, that almost every known tint may be satisfactorily represented.

Raised effects and ornaments in relief may be executed in colour by modelling with a clay paste upon the surface of the ware, exposing to heat, and then painting with coloured enamels. Photography has not as yet been employed directly as a decorative process. There are two mechanical processes, in addition to ordinary printing, for producing coloured decoration upon the glaze, namely "ground laying" and "bat printing." The first is employed when an even coloured surface is required. The parts to remain white are painted by hand with a mixture of potassic carbonate and some adhesive vehicle, and the whole is then coated with oil. The coloured glass, or mixture of metallic oxide and flux in an exceedingly fine powder, is dusted over the whole surface, and adheres to the oil. The ware is then dipped into water, and the alkaline stencil reacts with the oil immediately in contact with it, causes it to saponify and peel off, carrying the colour with it, and leaving the space white. The ware is then dried and fired. "Bat printing" is used when exceedingly sharp outlines are required, as for instance for crests and monograms. The pattern is very finely etched on a copper plate, to which oil is applied, but almost entirely removed by friction from the operator's palm. Films of gelatine or glue are applied to the copper plate, and absorb the residue of the oil remaining in the lines of the engraving. The gelatine is applied to the ware, and transfers the pattern in oil to its surface. Powdered enamel is dusted on, and adheres to the lines printed in oil by the gelatine film. Printing may be executed on the glaze in the same manner as on biscuit, by incorporating a flux with the ink, and moistening the paper with essence of turpentine before its removal; or by removing the paper by heat, and dusting an enamel colour upon the adhesive outline which remains. In the latter case, the ink contains no colouring oxide, but is only an adhesive mixture. The construction of small mills, for the reduction of gold and other colouring ingredients to the state of fineness required for painting or printing, is of considerable importance. The following are descriptions of two which are considered serviceable. In one, a number of glass "mullers" fixed in a frame, to which a horizontal eccentric motion is communicated, press by means of springs upon a slowly revolving glass table. In the second, a single oval glass muller moves over a 2-ft. ground-glass slab, which is caused to revolve in an opposite direction to the muller. The motion of both is so arranged that the muller shall successively pass over the entire surface of slab. The muller is grooved on its base, to prevent suction, and carries a scraper, which directs the substance to be ground between the grinding surfaces.

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(See Clay; Glass).

PRINTING and ENGRAVING (Fr., *Imprimerie et Gravure*; Ger., *Buchdruckerkunst und Stecherei*).

In the present article, the terms "printing" and "engraving" will be extended to embrace the following subjects:—Letter-press printing; printing in colours, and chromo-lithography; type-writing; autographic processes (manifold writers); engraving on wood, copper, steel, stone, and zinc; photographic processes (e. g. heliotype, Woodbury-type, Dallas-type, &c., &c.).

Letter-press Printing.—So little change has taken place of late years in the ordinary routine of letter-press printing, that there is no ground for an exhaustive essay on the subject. Progress is to be noted exclusively in the perfection of machinery for accomplishing the various objects, and to this branch, attention will be confined. It may be conveniently divided into four sections—composing-machines, printing-presses, finishing-machines, and cutting-machines.

Composing-machines.—One of the most remarkable inventions in connection with printing in modern times is the Clowes composing-machine, shown in Fig. 1162. It is the invention of John Hooker, a compositor in the employ of Wm. Clowes & Sons, Limited, of London and Beccles, and is in a certain degree based upon Mitchell's composing-machine exhibited in 1862. The machine is triangular, the sides measuring 5 ft., 5 ft., and 7 ft., the base forming the front. The table *a* is about 3 ft. above the floor; over it, travel a number (48) of endless tapes *b*, from the back towards a collecting-tape *c* passing from left to right. Over each of the tapes *b*, is a trough *d* filled with types lying on their sides, feet foremost. At the bottom of each trough *d*, is a little stop, on which the types rest; and just above it, on one side, is a knife or striker in communication with an armature. Electricity is provided by a couple of Grove's cells, or otherwise, and a series of wires connects the electro-magnet of each armature with the "setting-board," to be presently described. When the electric circuit is complete, the armature is attracted to its electro-magnet, and the striker pushes the lowermost type out of the trough upon the tape *b* immediately below it, by which it is conveyed to the collecting-tape *c*. The tapes *b* are driven by power at the rate of 7 in. a second, and the tape *c* at 21½ in.; the relative positions and speeds of the tapes *b* and *c* are so adjusted that each type shall unerringly assume the position corresponding to the order required by the matter to be printed. The setting-board *e* is placed in a convenient position for the compositor. It is divided into a series of copper discs describing the form of the receptacles of an ordinary lower case; each disc is connected by a wire with the electro-magnet of the letter indicated, while a second wire from the opposite pole of the battery terminates in a copper stylus, which is held by the compositor. Composition is effected by tapping with the stylus upon each disc in succession, according to the letters required; and as contact with any portion of a disc suffices to establish the circuit and bring down a type, while the area of the setting-board is only about 12 in. by 6 in., the process is exceedingly rapid. The setting-board does not embrace every letter and sign; those of rare occurrence are omitted, and a supply of them is kept in a small case *f* at the compositor's left hand, so that he can readily select them and get them into place by means of a little spout provided for the purpose over a spare tape. The composed matter forms one continuous line, which is removed at intervals and justified. Into this line, only one type can enter at a time; in case of any derangement or obstruction, a lever breaks the connection, and the machine is arrested till it has been rectified. The effective capacity of this machine amounts to 10,000 types hourly set up in page form, employing four lads setting, justifying, and replenishing the type-troughs. Only one fount can be used at a time, but the machine is adapted to take 4 or 5 different founts by simply exchanging the types.

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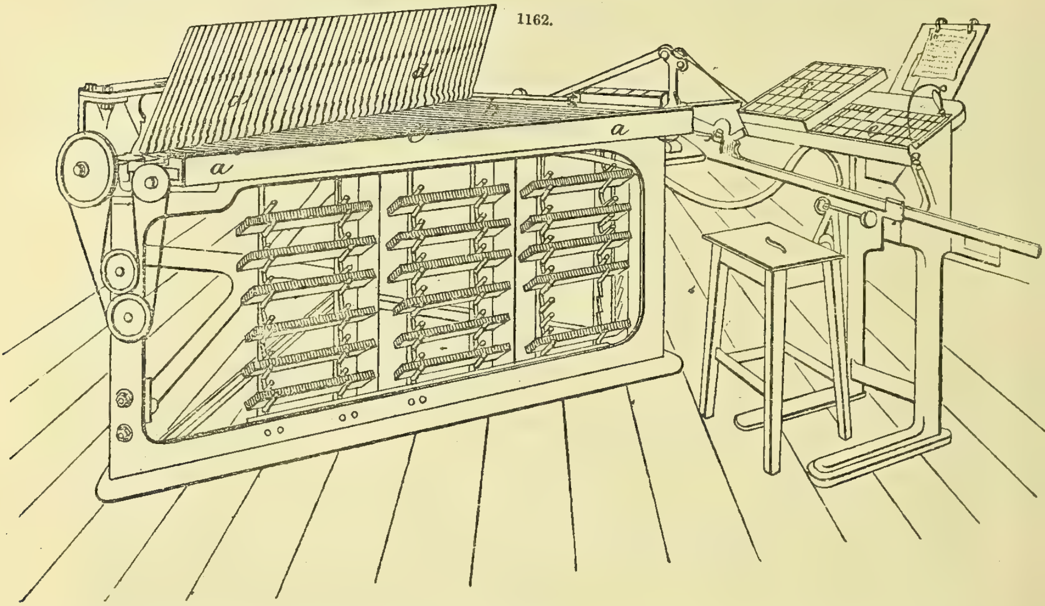
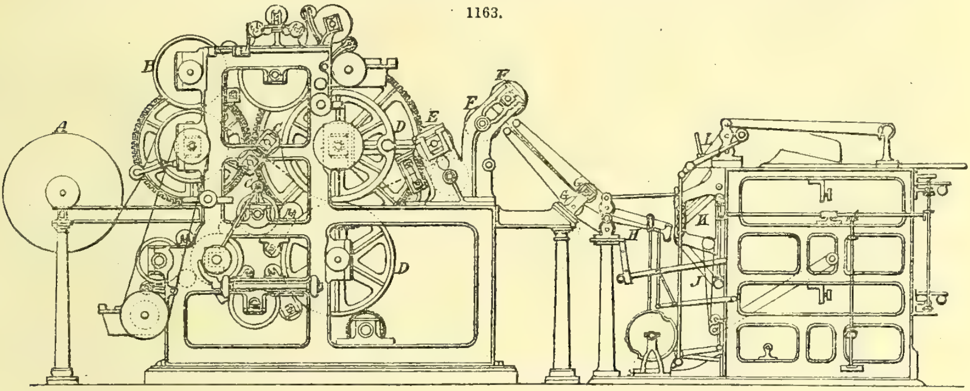


Printing-Presses.—In the article "Press" in 'Spons' Dictionary of Engineering,' pp. 2660–2670, will be found detailed descriptions and illustrations of the most notable improvements in printing-presses up to that date. Since then, the following has been introduced:—

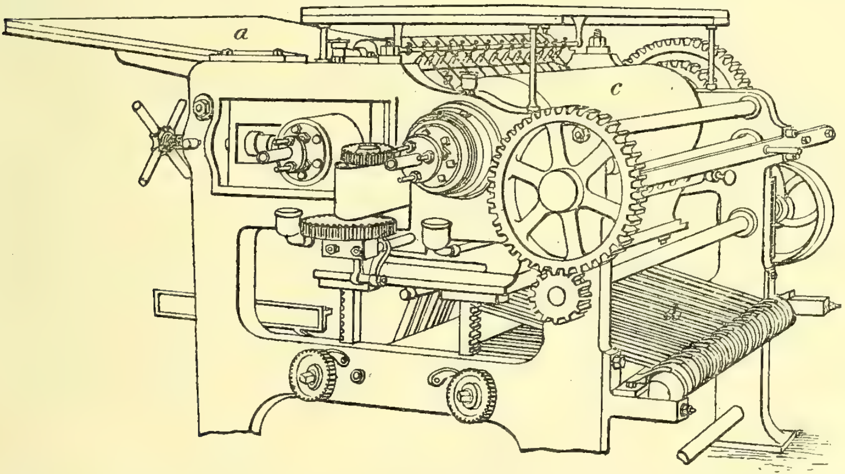
Ingram's.—This is a web rotary machine, invented for printing illustrated newspapers, and used for the *Illustrated London News* and other papers issued from the same office. It is the invention of W. J. Ingram, and is made by Middleton & Co., Lomán Street, Southwark. It is illustrated in section in Fig. 1163: A is the roll of paper, containing a length of 2–3 miles; B, the type- and impression-cylinders for printing the inner forme, or type-side of the paper; C, calendering- or smoothing-rollers, to remove the indentations produced by the impression of B, so that a smooth surface is preserved to receive the outer forme, or illustrated side of the paper, which is printed by D; E, cylinders, one provided with a saw-toothed knife, and the other with a corresponding indentation, to perforate the paper between each impression; F, rollers for holding the paper securely, to resist the effect of G, which are called snatching-rollers, and, being driven at a rather higher surface-speed than the holding-rollers, snatch or break the paper at the places where it has been perforated, and form it into separate sheets. As it is found that machinery for folding newspapers works much better at a moderate speed, in this case, it has been arranged in duplicate, so that each folder only works at half the speed of the printing-machine. The vibrating arm H delivers the sheets alternately to K and J, which are carrying-tapes leading to the two folding-machines. If the sheets are wanted unfolded, the arm H is moved to its highest position, and there fixed; it then delivers the sheets to the roller L, and, by means of a blast of air and a flier, they are laid in a pile on a table provided for them. This change can be made without stopping the machine. The dotted line from A to L indicates the course of the paper through the machine. The effective capacity is 6500 copies printed and folded per hour. This machine has proved so superior for all illustrated work that it is coming into use among first-class general printers.

1163.

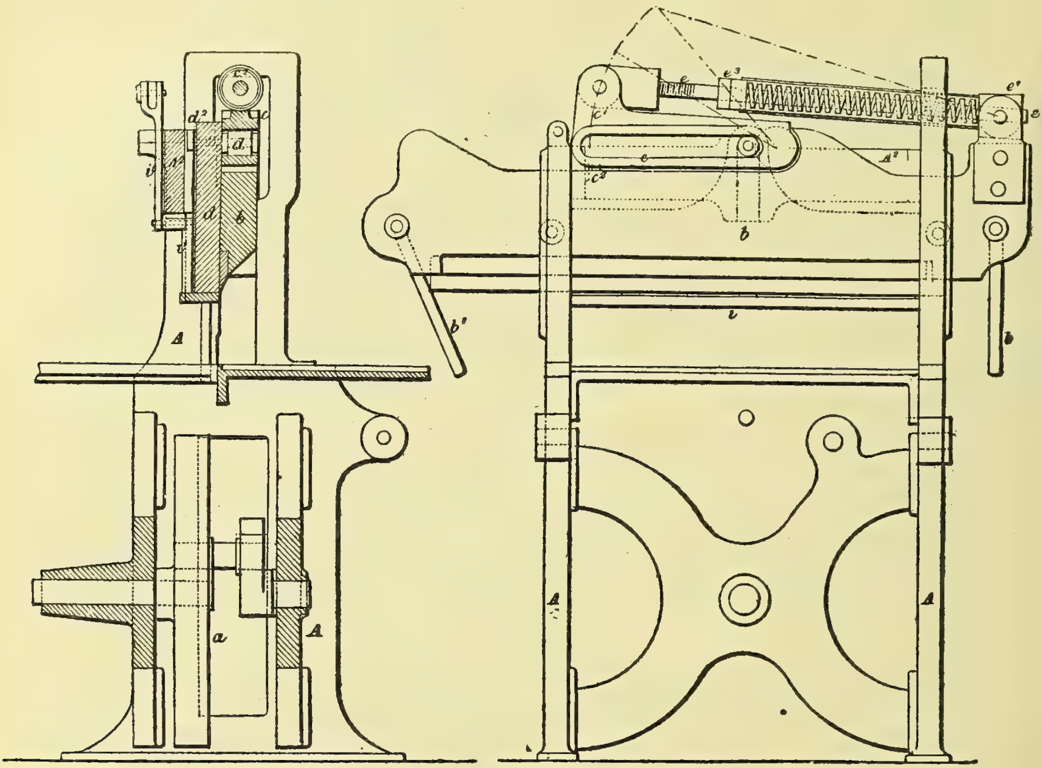


Finishing-machines.—Gill's rolling- and finishing-machine, made by Furnival & Co., Manchester, is in almost universal use among English printers. The latest improved form is shown in Fig. 1164. The printed sheets are fed from the table *a* by means of endless carrying-tapes *b*, between two rolls *c*, which are hollow, so as to receive steam, when it is desired to hot-roll the paper. The passage between the rolls gives a polished surface to each side of the paper. The finished sheets are delivered by another endless tape *d* to a table. An indiarubber "doctor" or scraper cleanses the faces of the rolls from any possible adhesion of ink after each sheet has passed through.

1164.



Cutting-machines.—One of the most improved "guillotines," or paper-cutting machines is that invented by Salmon & Capper, Manchester, and shown in Figs. 1165–6: A is the side frames; *a*, wheel with crank for giving motion to the knife-bar; *b*, knife-bar, with diagonal slots, to give the lateral movement as it descends; *b*′, parts of the rods between the knife-bar and beam; *c*, slotted link, jointed to the upper edge of *b*; *d*, clamping-plate, bearing a bowl *d*′ upon a stud, and a second bowl d^2 at the back. One end of the screwed rod *e* is jointed to a projection *c*′ from the link *c*, the other end sliding through a hole in a swivel-piece *e'*, having pivots carried by brackets bolted to the end of the knife-bar. A steel spring e^2 is placed upon the screwed bar, abutting against the swivel-piece at one end, and against screw-nuts e^3 at the other. When the knife-bar *b* descends, and the clamp *d* comes upon the paper to be cut, its descent is arrested, and as the knife-bar continues its downward movement, the bowl *d'* in the clamp remains stationary, acts upon the slotted link *c*, and causes it to assume a greater or less angle, according to the thickness of the paper being cut.


1165. 1166.

Printing in Colours, and Chromo-lithography.—Printing in colours as usually effected requires a separate impression to be taken for each colour, as great difficulty is experienced in combining the pigments for a polychrome print so as to complete the operation by one impression, on account of their varying densities and consistencies. W. G. White claims to have overcome the obstacle, and to have developed a process which is said to be in use on an extensive scale in Paris. His method, so far as divulged, is as follows. The prepared pigment chosen for the ground of the design is first run into a mould, so as to form a solid block about 3 in. thick. The pattern is traced with a steel point upon a sheet of "artificial talc," made from a mixture of collodion and oil, and this is pressed upon the block, so as to leave an impression of the lines upon its surface. The pattern is then cut out of the block by a sharp steel knife mounted on the end of an articulated parallelogram, so as to be maintained in a vertical position, while at the same time having a perfectly free horizontal motion. The various pigments forming the designs are then poured into the spaces cut out, a kind of mould being formed temporarily by a portion of the ground colour, supplemented by strips of wood soaked in water. The paint is poured in hot and liquid, and, as soon as it has cooled, another is added, and so on, until the whole design is finished, thus forming a complete mosaic. In the case of a large subject, various portions of the block may be executed by different operators at once, and then joined together; the method is also being tried of cutting out the whole pattern in wood or metal, by means of a band-saw, and then forcing the die so formed into the block of ground colour, so as to stamp out the colour therefrom. The mosaic, or "type," as it is called, is put into a powerful press, resembling that used by lithographers, and is first shaved by a heavy steel knife, so as to render the surface perfectly even and smooth. The material to be printed upon is then laid face downwards on the slightly moistened block, and a series of rollers are passed over it once or twice, when the impression is found to have completely penetrated its substance.

The print is exposed for a few seconds to the heat of a hot plate, for driving off the solvents employed, and perhaps fixing the colours, which are printed so permanently as to withstand exposure to the sun, and when a piece of velvet printed in this manner was boiled for 8 hours in strong potash solution, the colour did not entirely disappear. Water-colour drawings and oil-paintings may be reproduced by this process, so as to present the appearance of chromo-lithographs and oleographs respectively. But it is stated to have a far more extended application, in printing upon textile fabrics the designs of Gobelins and Arbusson tapestry, to form curtains, *portières*, &c. The range of materials capable of being treated appears to be extensive, as the same design has been reproduced upon fine silk and the coarsest jute sacking, both impressions, it is said, presenting all the necessary sharpness of outline.

Bacon's multicolour printing-press, shown at the recent fair of the American Institute, will print in 8 colours at a single impression. This is attained by a special arrangement of the inking-table, which, instead of being in a single piece, is composed of a number of narrow cast-iron plates held in a frame. These plates are formed of four distinct parts, and are wide in the centre and taper conically toward the extremities. This mode of construction allows them to move easily on each side at every revolution of the table, and has nearly the effect of an articulated joint. The end piece near the ink-trough is stationary. The various coloured inks are placed in the ink-trough, which is divided into cells by metallic partitions. Directly over the trough, is an iron frame carrying a set of screws and nuts. By tightening these screws, which are placed over the metallic partitions, the inks as they flow beneath are prevented from mixing. The inking-rollers, instead of being fixed at a certain angle relative to the table, are arranged so as to run perfectly straight, the distribution being effected by the plates. The inks are spread on the multiple table in the usual way. As a consequence of the motion of the articulated joint, the inking-table is caused to move slightly at every revolution of the table, and the ink is thus as well distributed as if several rollers were used. The movable plates which constitute the inking-table are of different widths, so that the uppermost or the lowest line in a page can be printed in a colour selected beforehand. Motion is communicated to the movable plates by a small lever which hangs under the table, and which rests on a small vertical iron plate affixed to a cross-stay of the machine.

Chromo-lithography varies from simple colour work to tinted lithography and oleography. All coloured lithographs require a separate stone for each colour; hence to ensure the correct position of each impression, it is necessary to have a "key-stone," on which the limits of each colour are distinctly and accurately laid down, the key-stone itself being omitted in the printing, except for common work. The "set-off" or "faint," which is the "trace" produced by an impression from the key-stone in an ordinary press (as described under Engraving on Stone), must have the exact dimensions of the original, to ensure which, it is best to use good, stout, cream-wove note-paper, taking care that it is dry and well rolled, and the key-stone quite dry, and performing the operation without delay. The impression may be dusted over with red chalk, and snapped with the finger-nail to remove excess, and may then be laid upon another stone, and passed through a press to communicate the image. As to the order in which the colours should be printed, this depends somewhat upon the effect desired, but the general rules are that a dust-colour should always precede (not follow), and that transparent colours should succeed opaque ones, the common order being (1) dust-colours, (2) blues, (3) reds, (4) yellows, (5) outline- and finishing-colours.

"Registering," or adjusting an already-printed sheet to the stone for further additions, is a delicate operation, which may be performed in three separate ways. The most simple is the "lay." The paper should possess well-defined corners and edges, and its size is determined before making a set-off. This done, a "lay" corresponding to the edge of the paper is made on the stone, and the subject is thus brought into position on the sheet, the lay being then drawn in fine lines of lithographic ink, so as to print on the set-offs throughout. A set-off is made for each colour, and the lay-mark is permanent. When printing a light colour, the lay-mark may be rendered permanent by covering the place with gum, and making scratches through it when dry to coincide with the marks replaced, marking with common writing-ink, and washing the gum away when dry. The second method is by needles, taking advantage of permanent lines in the picture, or making tiny marks at the edges. The needles consist of slips of wood or cane $1\frac{1}{2}$ in. long and $\frac{1}{4}$ in. thick, penetrated by a sewing-needle so that about 1 in. projects. The set-off on the stone is perforated by the needles at two opposite corners, and the sheet is pricked at the corresponding corners. The needles are passed through the sheet from the back, and the sheet is thus dropped into its place on the stone, while the operator withdraws the needles and his fingers. This method is simple when the paper exceeds the size of the stone. A third plan differs from the last only in having the needles fixed in a lath. These three methods (particularly the two first), though in very general use, present some objections, the removal of which is sought to be accomplished by two more recent plans. The first of these consists in letting leaden plugs about $\frac{5}{8}$ in. long and $\frac{1}{4}$ in. diameter into the stone for the reception of fixed wire pegs at the centre of each end of the stone, which are made to project about $\frac{1}{16}$ in., and to puncture each set-off. When the stone much exceeds the size of the paper, one peg may be soldered to a strip of brass tinned at the back, and fixed to the stone by blowing on a piece of shellac. The second improved method is to fasten two brass strips, shaped respectively like the letters | L, to the key-stone by means of shellac, and placing identical marks on each stone. Registering-machines have been devised, but are not in general use.

The paper for colour-printing must be thoroughly stretched by rolling after it comes into the lithographer's hands. The temperature and degree of moisture of the room must be kept as constant as possible, to prevent stretching and shrinking in the paper. When printing on damp paper, it must be kept damp by covering it, and placing it out of draughts. The drying of the ink after each impression is best done in a special apartment at a sufficiently high temperature; in this case, the paper should be similarly dried before making the first impression. The surface of the stone used is polished when pen or brush is to be employed, but grained for chalk and tints, the graining being coarser for colour than for black. The "setting-off" of colours may be avoided by dusting the printed sheets with a powder of chalk, talc, or magnesia, but this is liable to deaden the colours.

The tints for imitating the light washes of colour in water-colour drawings and similar work, are produced in various ways, on the principle of covering the stone with a fatty substance in such a manner that it would roll up of full strength all over, except where part had been removed. When chalk is to be imitated in the tints, the stone must be coarse, but very sharp-grained, and the set-off must be made clearly visible throughout the operation. The set-off being made on the grained stone, the margin and high lights are stopped out with gum and acid, and the ground is laid. Should the set-off be too weak, an impression dusted with red chalk or vermilion may be registered upon it, and lightly pressed. The ground forming the tint must be hard enough to bear scraping without smearing, must roll up solidly after etching, and must be removable by solvents of fats. Of the several substances that may be used, preference is given to Brunswick-black and copal-varnish. The evenly laid ground is left to dry, and the lights are put in by the scraper and preserved by etching. In producing tints of various gradations, the ground must not be laid on with the roller, as in the preceding case, but by warming the stone, and applying "rubbing-in" ink till the grain is filled in, then removing the excess of ink by a piece of woollen. The whole subject of tints, and the pigments and driers employed to produce them, is one of great intricacy, and demands unusual care and experience. The best works on the subject will be found quoted in the bibliography at the end of this article.

Mention may here be made of a machine and process designed by Arthur Rigg for doing away with the necessity for having a separate stone for each colour, at least in the case of such work as map-outlines. These outlines are laid down on a thin sheet of brass, and the various colours, placed side by side in cakes in an iron frame, are cut apart by scissors. Each piece of brass is then laid upon a cake of the required colour, and made to adhere to it, and the colour is cut to the exact form of the plate by a small wire-band saw. When all the pieces are furnished with colour, the whole is put together in the chase, and welded into homogeneity by warmth and pressure. The coloured ground-work being printed, an impression from the black "key-stone" is made on the top.

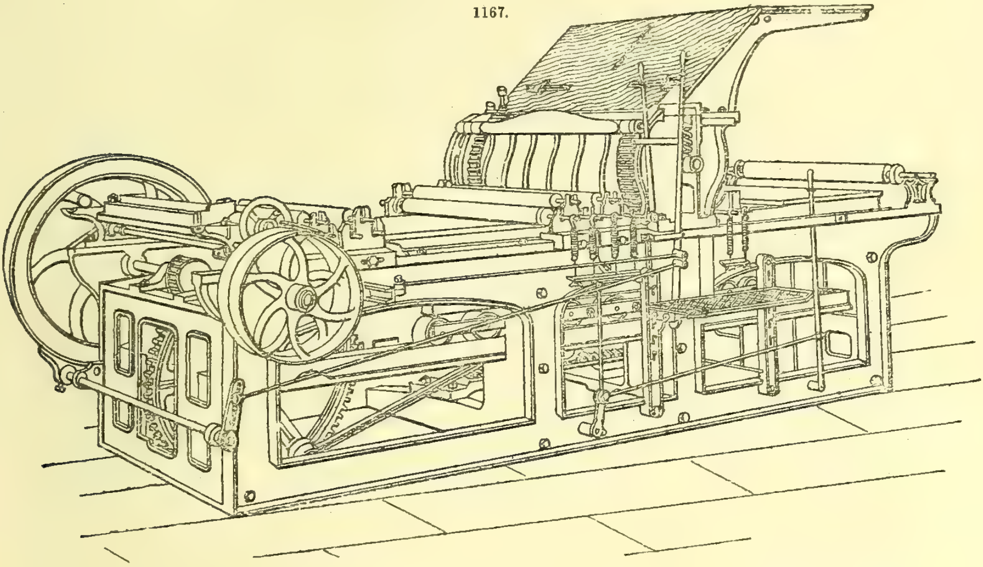
The chromo-lithographic machine made by G. Mann & Co., Leeds, and in most general use in this country, as well as largely on the Continent, is shown in Fig. 1167.

Type-writing.—During the last 25 years, a great number of machines have been introduced for writing by means of type-letters. The following are the most notable examples.

J. Pratt's (of Alabama) has the type fitted on the face of a small plate, about ¾ in. sq. This is supported vertically before a frame carrying the paper by an arrangement of levers capable of giving it both vertical and horizontal motion. The plate is thus shifted into any position, and any type required can be brought opposite the point where the impression is taken. As this is done, the same mechanism which moves the plate sets in motion a small hammer, which strikes the paper on the opposite side to the plate, and forces it against the type, thus producing an impression. When the carbon paper is used, several copies can be taken. In order to limit the number of keys required to operate the levers for shifting the type-plate, there is one set of keys for giving the vertical movements, and another for giving the horizontal movements. Thus, for each letter it is required to move two keys; but as each key of one set could be used with each key of the other set, a much smaller number of keys is necessary than if one key were requisite for every letter. It may make it appear clearer to say that the depression of one key brings into position the vertical line containing the type wanted, and the horizontal line containing the same type; consequently the intervention of the two lines, where the special letter needed is to be found, is brought into the proper place for the impression. The paper is carried in a small frame, traversed after each letter by a rachet-wheel and pall. At the end of a line, the frame is raised by a rack worked by a separate key, and at the same time thrown back to the proper side of the machine for commencing a fresh line.

Sir C. Wheatstone invented several type-writing machines. No. 1 is in its main features somewhat like Pratt's. The paper is held in a vertical frame sliding in guides across the machine, and the impression is produced by the blow of a small hammer on the type, the paper being interposed between the hammer and the type, and the type moved to its proper place each time. The differences, however, in the methods of mounting the types and actuating the mechanism are very great. The type is set in three rows on the periphery of a small wheel on a vertical spindle. Thus, by shifting the wheel up or down (in the direction of its axis) the line containing the letter required is brought to the proper point on a level with the hammer, and by rotating the wheel, the letter itself is brought round. Both these motions are effected by depressing the same key, there being a key corresponding to each letter on the type-wheel. The spindle of the type-wheel is rotated by a spring, which gives the traverse to the paper, and which therefore is wound up by drawing the frame back to its original position after the completion of each line. The depression of the key, acting through an arrangement of levers, raises the type-wheel to the required height, and, at the same time, sets free a catch, so that the wheel is turned round by the spring till it is caught by the second catch, the position of which corresponds with that of the letter required. The hammer is worked by an arrangement something like that used in the piano, and so mounted that the blow is given after the type has been brought into position. The action is somewhat heavy, and unless the key is depressed sharply, and with a little jerk, the hammer is not operated, and consequently no impression results. But the machine as it stands is capable of very satisfactory work. The other three forms are on a different principle, but much alike among themselves. The types are set each on the end of a small lever, and these levers are arranged side by side in the form of a quadrant, each lever being pivoted freely. The whole set of levers is connected with a sliding plate, by shifting which to the right or left a suitable distance, any one of the levers is brought over the point where the impression is to be taken. The type being thus held over the proper spot, a small hammer strikes it down on the paper below. The sliding plate extends along the front of the instrument parallel with the row of keys, which resemble piano-keys. It has in it a number of slots, into each of which a pin slides, the arrangement being such that each pin and slot moves the plate a certain distance, differing from that to which any other pin moves it, and corresponding with the distance necessary to bring the letter required into action. Each pin is actuated by one of the keys of the key-board. Thus, by depressing the proper key, any required letter is brought under the hammer. The types are charged with ink by being brought against an inking-pad at each side, as they move. The paper on which the impression is to be received is fitted on a cylinder, which is revolved continuously. The writing is consequently carried round and round the cylinder. As soon as it reaches the spot where it began, the cylinder is shifted longitudinally, so that a fresh line is commenced. There seems no reason why a reciprocating plate, with suitable means for shifting it at the end of the line, should not be substituted for the obviously inconvenient cylinder. With this improvement, perhaps, a machine of this character might be brought into practical use. In its present form, the arrangement which prevents the use of paper of any other than a certain size and shape is a considerable drawback.

1167.



In R. M. Hansen's "writing ball," the chief peculiarity is that the keys are all arranged over a semi-spherical surface, which, to a certain extent, conforms to the shape of the hands. The keys are formed of pistons, set as radii of the sphere, so that each key strikes at the same spot. The keys are depressed directly by the fingers, and are raised by small springs. The paper (carbonized and white) is carried either by a cylinder or a plate under the "ball." In the original machine, the paper was moved continuously by clockwork, or a small electrical motor; but in the more recent forms, the paper is traversed by a movement derived from the key which is depressed. This slightly depresses the bed on which the paper is supported, and by suitable apparatus, this movement is caused to carry the paper forward a single space. It is stated that with practice, great rapidity can be attained by the machine, and the direct action of the keys on the paper enables considerable force to be applied, and consequently a large number of "manifolded" copies to be obtained.

The "Remington" machine has in front a key-board holding the letters and numerals; on pressing any one of the keys, a small lever bearing the corresponding letter is made to strike against a ribbon saturated with prepared ink (presumably glycerine and an aniline violet), over which, the paper is held on a roller. Each letter strikes at the same spot, but the roller and paper move one space forward after each letter, so that each letter falls into its proper place. The mechanism is very simple, the levers carrying the letters being actuated by an arrangement similar to that of a piano, and strung on a circular wire, so that they all strike into the centre of the circle. As soon as a line is finished, the roller is taken back to its original position by a treadle, and is at the same time revolved one tooth of a rachet-wheel, so as to bring a fresh line under operation. The type is all "small capitals," and the printing is regular and even. It is said to be easy to attain twice the speed of ordinary writing. The machine will "manifold" about 20 legible copies with carbon-paper.

In A. Barlow's machine, a vertical cylinder carries the types, and is raised or lowered to bring the required letter opposite the place on the paper where it is to be impressed. This raising or lowering is effected through the action of one key, which, being raised or lowered to a certain height, acts through suitable mechanism to raise or lower the type-cylinder likewise. The key is slotted with a number of slots corresponding to the .number of letters; the finger being placed over the slot, and the key depressed, it descends until it reaches the level of a pin which enters the slot and is stopped by the finger. All the other pins pass freely through their slots.

The "Crandall" type-writer (Caldwell, New York), is a small machine costing 10*l.*, weighing 9 lb., mechanical and automatic in action, self-contained, and manipulated by 27 keys. It writes capitals, small letters, script, numerals, and all the various stops and signs. The keys are grouped to facilitate the writing of oft-recurring small words. Each letter is written in front of the operator, and can be seen as soon as written; 60–70 words a minute can be written after short practice, and over 100 by experts. It manifolds readily. Circulars written by it go as "printed matter" by post.

Autographic Processes—Manifold Writers.—Perhaps the most simple and effective methods of obtaining a very limited number of copies of a document by one operation of writing are the ordinary pencil and carbon-paper, and the familiar copying-ink and tissue-paper. For obtaining a large number of copies, however, while too few for a lithographic press, several methods have been recently introduced.

In Zuccato's "papyrograph," a sheet of fine paper is saturated with a resinous varnish, and dried. On it, writing is made with an ink consisting of a strong solution of caustic soda, slightly coloured in order to be more obvious to the eye. The soda immediately attacks the resinous preparation of the paper, converting it into a soap. The sheet is floated on water, the written side being upwards; the water soon penetrates the softened parts, making the written lines stand up in bold relief as ridges of fluid. The paper is now removed from the surface of the water, and pressed between folds of blotting-paper, after which it is once more floated on the surface of the water, and again blotted off, in order to remove the remainder of the resin soap. The sheet thus prepared forms a stencil, of which the general ground is impervious to moisture, while the written lines, being denuded of varnish, are quite porous, and afford an easy passage to an aqueous liquid. In the early days of papyrograph printing, a pad, saturated with persulphate of iron, was placed at the back of the stencil, while the paper to be printed on was moistened with a solution of ferrocyanide of potassium. The iron salt being forced through the porous lines by a gentle pressure, reacted on the ferrocyanide; a blue impression was the result. It is now, however, found to be more convenient to print from the stencil by means of an aniline colour dissolved in glycerine, and the colouring power of this kind of ink is so great that dry paper may be used for receiving the impression. On a velvet pad which has been moistened with a solution of aniline blue in glycerine, is laid the paper stencil, this having been previously brushed over at the back with a little of the ink. It is now merely necessary to place sheets of paper on the upper face of the stencil, and to apply gentle pressure by means of an ordinary copying-press, in order to obtain copies rapidly and easily. The copies can be printed off more quickly by this process than by typography or lithography. About 600 copies can generally be taken from one stencil.

Another class of printing stencil is made by the mechanical perforation of suitable paper or tissue. Stencils perforated by a rapidly rising and falling needle-point, actuated by a treadle, have long been used for the printing of embroidery patterns. In such a case, powdered colour, mixed with resin, is dusted through the stencil, after which the device is fixed by the application of sufficient heat to soften the resin. Edison proposes to use such perforated stencils for ordinary autographic printing purposes, and replaces the complex treadle perforating-machine by a kind of pen, in which a needle-point is made to move rapidly up and down by means of a small electric motor attached to the instrument. When Edison's electric pen is connected with a battery of two elements, the needle rapidly passes in and out of the perforated point of the instrument. If written with on a piece of blank paper, the paper becomes perforated. The sheet of ink-proof paper having been written on with the electric pen, can be used as a printing stencil by merely laying it down on a sheet of white paper and passing an inking-roller over its back. The operation of printing is very rapid, so that many copies can be produced in a short time. Other perforating pens have followed in the wake of Edison's electric instrument, among which may be mentioned the "horograph," a very convenient and portable clockwork pen, manufactured by Newton, Wilson, & Co., of Cheapside. A pneumatic pen, in which the motive power is a stream of air supplied from a foot-bellows, has also been introduced into the market. A still more complex and expensive arrangement than either of the preceding, for producing perforated stencils, consists of an induction coil, capable of giving a sufficiently powerful spark to perforate the stencil-paper; and this spark is made to continually pass between a partially insulated metallic pen and a metallic plate, on which the stencil-paper is laid.

All these perforating arrangements have the disadvantages of being expensive, complex in construction, and liable to get out of order when used by unskilled persons, while the perpendicular position in which the mechanical perforating pens must be held, necessarily hampers the freedom of the writer. In a new perforating method recently introduced by Zuccato, the impervious stencil-paper is laid on a hardened steel plate, cut on the face like a fine file, and the writing is executed by means of a point or style of hardened steel. Under these circumstances, the teeth of the file-like plate perforate the paper wherever the point of the style exerts pressure, and a stencil eminently adapted for printing from is the result. This kind of printing is called "trypograph." A sheet of the prepared paper is laid on the file-like plate and written upon with the hardened steel pencil, the operation of writing being as easy as if a pencil were employed. By fixing the stencil on the frame of a desk-like press, placing a sheet of white paper underneath, and then pushing over the upper surface of the stencil an indiarubber scraper or squeegee charged with printing-ink, the ink passing through the perforation produces a copy of the original writing. As many as 6000 copies can be obtained from one stencil. Thin metallic plates are readily perforated by Zuccato's method, and calico receives the trypographic impression admirably.

Pumphrey's "collograph" depends on the fact that when a film of moist bichromated gelatine is brought into contact with ferrous salts, tannin, or certain other substances, the gelatine is so far altered as to acquire the property of attracting a fatty ink. Pumphrey supplies plates of slate or glass covered on one side with a thin film of gelatine, and these are prepared for use by being soaked in a weak solution of potassium bichromate, all excess of moisture being then removed by first wiping with a cloth, and afterwards rolling paper on the damp surface. A drawing or writing, which has been made with either an ordinary iron and gall-nut ink, or with a special ink, is transferred to the prepared plate, just as in the case of the transfer to zinc. The original being removed, the plate is inked by means of a roller, moistened by a sponge, in order to remove any trace of ink from the ground, and then printed from, much as if it were a lithographic stone, or a zincographic plate.

There are some methods, which are rather copying than printing processes, as they depend on the writing of an original with a very intense ink, and then dividing the ink, so as to obtain a number of feebler copies. The ordinary method of obtaining one or two reverse copies of a letter on thin paper is of this nature; but these processes, which are capable of yielding 30–60 fairly good copies, depend on the use of a solution of an aniline colour for writing. In the case of copying processes introduced by Pumphrey and Byford, the writing is executed with a strong solution of an aniline colour on thin, and tolerably hard, paper. The writing quite penetrates the thin paper, and on pressing a sheet of moistened paper against the back of the original, some of the aniline colour will set off on the damp paper, giving a direct copy of the original writing. In the same way, numerous copies may be produced; but processes of this kind cannot reproduce very fine lines with distinctness. A somewhat analogous arrangement for obtaining numerous copies is afforded by Waterlow's "multiplex copying portfolio" and its contents. The writing is done with the aniline ink, and a damp sheet of very soft and porous paper is pressed down on the writing. This soft paper absorbs a large proportion of the aniline ink, and itself forms a reversed printing-surface, capable of yielding a considerable number of direct copies to damp sheets of paper.

The just-described copying processes labour under the disadvantage of requiring the use of damp paper for receiving the impression; but this difficulty has been overcome in an arrangement which has been introduced under the names of "hectograph" and "chromograph," these differing from each other rather as regards detail than kind. The writing is executed on ordinary writing-paper with an aniline ink, and when the lines have dried, the original is transferred to the surface of a slab of soft gelatinous composition, analogous to that used for making printers' rollers, contact being established by a gentle rubbing with the hand. The original, after being allowed to remain in contact with the gelatine slab for about two minutes, is stripped off, leaving the greater part of the ink on the gelatine. To obtain the copies, it is now merely necessary to lay paper on the slab, and either rub down with the hand, or establish contact by means of a soft roller. The requisite number of copies having been obtained, or the colour on the lines being exhausted, the slab can be cleaned by means of a damp sponge, when it is again ready for use. A composition for making the slab may be prepared as follows:—1 lb. of gelatine is soaked in water until it becomes flaccid, after which it is melted, in a water-bath, with 6 lb. of common glycerine, the heat being maintained for a few hours so as to drive off all excess of water. The mixture is then poured out into zinc trays ½ in. deep, and allowed to set. The ink may be prepared by dissolving one part of aniline violet (blue shade) in a mixture of seven parts of water and one of alcohol. Letters written in coloured inks will give 150 copies, and in special black ink, 50 copies. The process is also known as the "Vienna multicopyist." Another composition for the slab consists of 130 parts water, 75 sulphate of baryta, 30 gelatine, 30 sugar, 180 glycerine.

Engraving. *On Wood.* The Block.—The best wood for the purposes of the engraver is box (see Timber), whether English, American, or Levantine; it should be light straw-yellow in colour, and free from black or white spots and red streaks, which indicate a soft wood. Small wood is generally pretty free from blemishes. The supply of good box-wood is by no means plentiful, and several other kinds of wood have been proposed or adopted as substitutes, the principal being sycamore and pear (much used for large coarse cuts, but too soft and irregular for fine work), *piacha*, persimmon, and American dog-wood; all these are described in the article on Timber. A substance deserving careful trial for this purpose is celluloid (see pp. 610–8), which might be obtained in sheets of any desired size. When wood is used, a large cut often necessitates the bolting together of several small ones. Wood blocks are about 1 in. high, and are then planed down to the exact height of type, and brought to a very smooth surface. They require keeping for some months to become seasoned.

Drawing on the Block.—Before any drawing can be made on the polished surface of the block, the latter must receive a slight wash. This is made with water and Chinese white, or very fine Bath-brick dust, or the scrapings of glazed cardboard; it is gently rubbed off when dry, leaving a surface on which the pencil will take. A tracing of the outline of the subject is made, and placed on the block with a piece of transfer-paper between, remembering that the picture will be reversed in printing. Every line is gone over with a sharp point. The outlines are then corrected and completed by a sharp-pointed H H H H pencil, the tints being afterwards filled in by a softer pencil, or thin washes of Indian-ink, to show the effects of light and shade. All washes must be used with such care as not to affect the wood by their moisture. The portions of the block not under immediate operation are kept covered with smooth, blue, glazed paper, to preserve them from injury, and reduce the glare from the lamp.

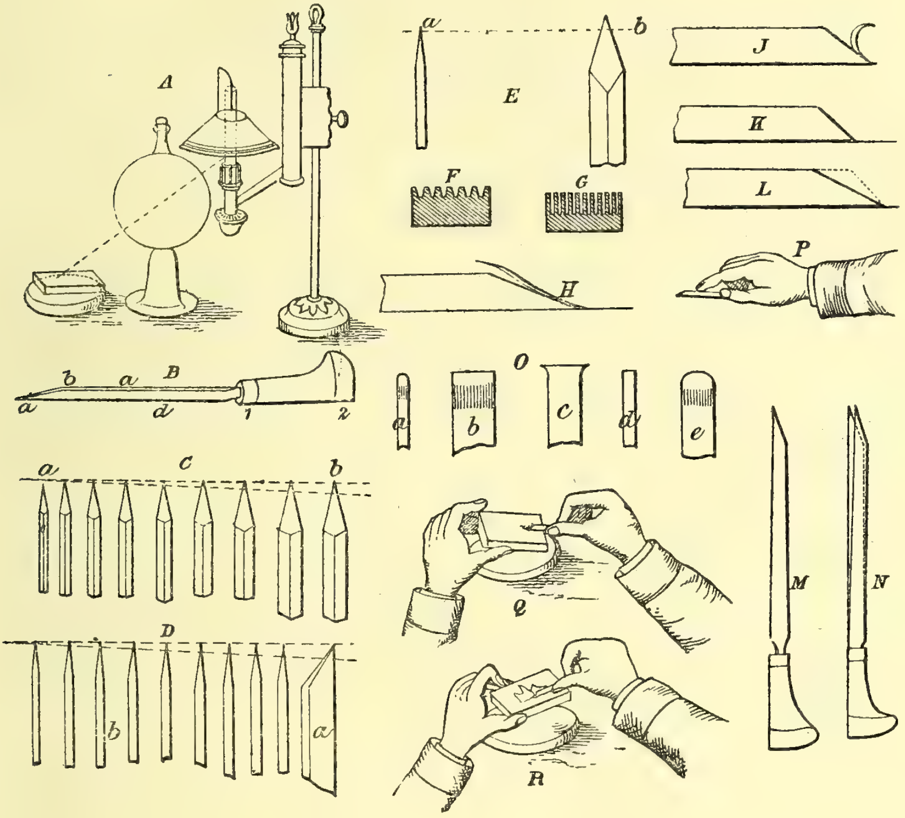
Proofing.—When the drawing is finished, a proof may be taken in the following manner, before blocking out the cut, that is, before the superfluous wood is cleared away:—Rub down a little printing-ink on a slab till it is fine and smooth; take some of this on a silk dabber, and carefully dab the block until sufficient ink is left upon the surface, without allowing any to sink below it. Lay a piece of India paper on the block, with about 2 in. margin all round; on this, place a thin smooth card; rub this over with the burnisher, taking care not to shift the card or paper.

The Lamp.—A clear and steady light, directed immediately upon the block to be cut, is a most important point, and in working by lamplight, it is necessary to protect the eyes from the heat and glare. The lamp shown at A, Fig. 1168, can be raised or lowered at pleasure, by sliding the bracket up or down the standard, it being fixed in the desired position by means of the small set-screw. A large globe of transparent glass, filled with clean water, placed between the lamp and the block, causes the light to fall directly upon the latter. The dotted line shows the direction of the light; by lowering the lamp, this light would take a more horizontal direction, thus enabling the engraver to work farther from the lamp. A shade over the eyes is occasionally used as a protection from the light of the lamp.

The Tools.—The tools consist of gravers, tint-tools, gouges or scoopers, flat-tools or chisels, and a sharp-edged scraper, something like a copper-plate engraver's burnisher, which is used for lowering the block. Of each of these tools, several sizes are required.

The "outline-tool," B, Fig. 1168, is chiefly used for separating one figure from another, and for outlines: *a* is the back of the tool; *b*, the face; *c*, the point; *d* is technically termed the belly. The horizontal line 1–2 shows the surface of the block. All the handles when received from the turner are circular, but as soon as the tool has been inserted, a segment is cut away from the lower part, so that the tool may clear the block. The blade should be very fine at the point, so that the line it cuts may not be visible when the block is printed, its chief duty being to form a termination to a number of lines running in another direction. Although the point should be fine, the blade must not be too thin, for it would then only make a small opening, which would probably close up when the block was put in the press. When the tool becomes too thin at the point, the lower part must be rubbed on a hone to enable it to cut out the wood instead of sinking into it. Nine "gravers" of different sizes, starting from the outline-tool, are sufficient for ordinary work. The blades as made are very similar to those used in copper-plate engraving; the necessary shape for wood engraving is obtained by rubbing the points on a Turkey stone. The faces, and part of the backs, of nine gravers are shown at C, Fig. 1168; the dotted line *a–c* shows the extent to which the tool is sometimes ground down to broaden the point. This grinding rounds the point of the tool, instead of leaving it straight, as shown at *a–b*. Except for the parallel lines, called "tints," these gravers are used for nearly all kinds of work. The width of the line cut out is regulated by the thickness of the graver near the point, and the pressure of the engraver's hand.

1168.



The parallel lines forming an even and uniform tint, as in the representation of a clear sky, are obtained by what is called the "tint-tool," which is thinner at the back, but deeper at the side, than the graver, and the angle of the face at the point is much more acute, as shown at D, Fig. 1168: *a* is a side view of the blade; *b* shows the faces of nine tint-tools of varying fineness. The handle is of the same form as that used for the graver. The graver should not be used in place of the tint-tool, as, from the greater width of its point, a very slight inclination of the hand will cause a perceptible irregularity in the distance of the lines, besides tending to undercut the line left, which must be carefully avoided. E, Fig. 1168, shows the points and faces of the two tools, from a comparison of which, this statement will be readily understood. As the width of the tint-tool at *b* is little more than at *a*, it causes only a very slight difference in the distances of the lines cut, if inclined to the right or the left, as compared with the use of the graver. Tint-tools that are strong in the back are to be preferred, as less likely to bend, and giving greater freedom of execution than weak ones. A tint-tool that is thicker at the back than at the lower part, leaves the black raised lines solid at their base, as at F, Fig. 1168, the block being less liable to damage than in the case of G, Fig. 1168, in which the lines are no thicker at their base than at the surface. The face of both gravers and tint-tools should be kept long rather than short; though if the point be ground too fine, it will be very liable to break. When, as at H, Fig. 1168, the face is long,—or, strictly speaking, when the angle formed by the plane of the face and the lower line of the blade is comparatively acute,—a line is cut with much greater clearness than when the face is comparatively obtuse, and the small shaving cut out turns gently over towards the hand. When, however, the face of the tool approaches to the shape seen at J, Fig. 1168, the reverse happens; the small shaving is ploughed out rather than cleanly cut out, and the force necessary to push the tool forward frequently causes small pieces to fly out at each side of the hollowed line, more especially if the wood is dry. The shaving, also, instead of turning aside over the face of the tool, turns over before the point, and hinders the engraver from seeing that part of the pencilled line which is directly under it. A short-faced tool of itself prevents the engraver from distinctly seeing the point. When the face of a tool has become obtuse, it ought to be ground to a proper form; for instance, from the shape of the figure K to that of L, Fig. 1168.

Gravers and tint-tools, when first received from the makers, are generally too hard—a defect that is soon discovered by the point breaking off short as soon as it enters the wood. To remedy this, the blade of the tool must be tempered to a straw-colour, and either dipped in sweet oil, or allowed to cool gradually. If removed from the iron while it is still straw-coloured, it will have been softened no more than sufficient; but should it have acquired a purple tint, it will have been softened too much, and instead of breaking at the point, as before, it will bend. A small grindstone is of great service in grinding down the faces of tools that have become obtuse. A Turkey stone is a very good substitute, as, besides reducing the face, the tool receives a point at the same time; but this requires more time. Some engravers use only a Turkey stone for sharpening their tools; a hone in addition is of great service. A graver that has received a final polish on a hone cuts a clearer line than one which has only been sharpened on a Turkey stone; it also cuts more pleasantly, gliding smoothly through the wood, if it be of good quality, without stirring a particle on either side of the line. The gravers and tint-tools used for engraving on a plane surface are straight at the point, as represented at M, Fig. 1168; but for engraving on a block rendered concave in certain parts by lowering, it is necessary that the point should incline slightly upwards, as at N, Fig. 1168. The dotted line shows the direction of the point used for plane-surface engraving. There is no difficulty in getting a tool to descend on one side of a part hollowed out or lowered; but unless the point is slightly inclined upwards, as shown, it is extremely difficult to make it ascend on the opposite side, without getting too much hold, and thus producing a wider white line than intended.

Gouges O, Fig. 1168, of different sizes are used for scooping out the wood towards the centre of the block; whilst flat tools, or chisels, are chiefly employed in cutting away the wood towards the edges, about $\frac{1}{8}$ in. below the subject. The gouge is similar to an ordinary carpenter's gouge, except that it is solid, being a round bar, with the end ground off at an angle. The other articles required are a sand-bag, on which to rest the block whilst engraving it; an agate burnisher and a dabber, which are used for taking proof-impressions of the woodcut; an oil-stone, and eye-glass with shade.

Holding the Graver.—Engravers on copper and steel, who have much harder substances than wood to cut, hold the graver with the forefinger extended on the blade beyond the thumb, as at P, so that by its pressure the point may be pressed into the plate. As boxwood, however, is much softer than these materials, and as it is seldom of perfectly equal hardness throughout, it is necessary to employ the thumb at once as a stay or rest for the blade, and as a check upon the force exerted by the palm of the hand, the motion being chiefly guided by the forefinger, as shown at Q, Fig. 1168. The thumb, with the end resting against the side of the block, in the manner represented, allows the blade to move backwards and forwards with a slight degree of pressure against it, and in case of a slip, it is ever ready to check the graver's progress. This mode of resting the thumb against the edge of the block is, however, only applicable when the cuts are so small as to allow the graver, when thus guided and controlled, to reach every part of the subject. When the cut is too large to admit of this, the thumb rests upon the surface of the block, as at R, Fig. 1168, still forming a stay to the blade of the graver, and checking at once any accidental slip.

Plugging.—If a slip or mistake occurs in a woodcut, it may be remedied by the insertion of a plug into a hole drilled in the block. If the error is a small one, the hole need not be deep; but if a large piece has to be inserted, it must be deeper in proportion. A plug is cut, of a round, taper shape; the small end is inserted in the hole, and the plug is driven down, without, however, using too much force. The top of the plug must then be cut off, and carefully brought to a smooth surface, level with the rest of the block; if this is not done, the plug will be visible on the print. If the error to be remedied happens to be in a long line, a hole must be drilled at each end, and the wood between the two holes removed by small chisels, the hollow space being filled up in a similar way to that described.

On Copper.—Engraving on copper is performed by cutting lines representing the subject on a plate of copper by means of a steel graver or "burin."

The Plate.—The plate must be perfectly polished, quite level, and free from imperfection; to this, must be transferred an exact copy of the outlines of the drawing. To do this, the plate is uniformly heated in an oven or otherwise, till it is sufficiently hot to melt white wax, a piece of which is then rubbed over it and allowed to spread, so as to form a thin coat over the whole surface, after which, it is left in a horizontal position till the wax and plate are cold. A tracing having been taken of the original design with a graphite pencil on a piece of thin tracing-paper, it is spread over the face of the prepared plate, with the lines downwards, and, being secured from slipping, a strong pressure is applied, by which operation the lines are nearly removed from the paper, being transferred to the white wax on the plate. The pencil-marks on the wax are now traced with a fine steel point, so as just to touch the copper; the wax is then melted off, and a perfect outline will be found on the copper, on which the engraver proceeds to execute his work.

The Tools.—Besides the graver, ending in an unequal-sided pyramidal point, the other instruments used in the process are a scraper, a burnisher, an oil-stone, and a cushion for supporting the plate. In cutting the lines on the copper, the graver is pushed forward in the direction required, being held at a slight inclination to the plane of the copper. The use of the burnisher is to soften down the lines that are cut too deeply, and for burnishing out scratches in the copper; it is about 3 in. long. The scraper, like the burnisher, is of steel, with three sharp edges to it; it is about 6 in. long, tapering towards the end. Its use is to scrape off the burr raised by the action of the graver. To show the appearance of the work during its progress, and to polish off the burr, engravers use a roll of woollen, or felt, called a rubber, which is used with a little olive-oil. The cushion, which is a leather bag about 9 in. in diameter, filled with sand, for laying the plate upon, is now rarely used except by writing engravers. For architectural subjects, or for skies, where a series of parallel lines is wanted, a ruling-machine is used, which is exceedingly accurate. This is made to act on an etching ground by a point or knife connected with the apparatus, and bit-in with aquafortis (commercial nitric acid) in the ordinary way.

Facing with Iron.—The relative hardness of iron and copper furnishes a means of greatly increasing the number of impressions that may be taken from a copper plate. Ordinary copper plates will not afford more than 800 good impressions without re-touching. This may be successfully increased to 2000 by electro-depositing a surface of iron upon the plate, and this surface may be renewed indefinitely. The necessary apparatus consists of a Bunsen's battery (20 elements) and a guttapercha-lined trough (45 in. long, 22 in. wide, 32 in. deep) filled with a solution of 100 lb. sal ammoniac to 1000 lb. water; to the positive pole of the battery, is attached a sheet of iron of the dimensions of the trough, and immersed in the liquid, while another plate of half the size is similarly fixed to the negative pole. After several days, the bath should be fit for use, the battery having meantime received necessary attention. The iron sheet at the negative pole is now replaced by the copper sheet to be coated, and momentary immersion should suffice to cover it with an iron deposit; if not, the bath is not yet ready. The copper plate must not remain in the bath after the bright iron coating appears blackish at the edges. Immediately the coated copper plate is removed from the bath, it is carefully washed under a water-jet of some force; when dry, it is again washed with spirit of turpentine, and is ready for printing from. Before re-coating the plate, the residue from the former coat must be removed by washing in nitric acid diluted with 8 parts of water, taking care to cleanse the plate from this acid liquid the moment the iron has disappeared, or the copper will begin to undergo similar destruction.

On Steel.—Engraving on steel is the same as copper-plate engraving, except in certain modifications in the use of the acids; therefore, so far as the process itself is concerned, no particular description is necessary; but the means employed for first decarbonizing and recarbonizing the steel plate, so as to reduce it to a proper state for being acted upon by the graving tool, must be explained. In order to decarbonate the surfaces of cast-steel plates, by which they are rendered much softer and fitter for receiving either transferred or engraved designs, fine iron-filings, divested of all foreign matters, are used. The stratum of decarbonated steel should not be too thick for transferring fine and delicate engravings; for instance, not more than three times the depth of the engraving; but for other purposes, the surface of the steel may be decarbonated to any required thickness. To decarbonate it to a proper thickness for a fine engraving, it is exposed for four hours to a white heat, enclosed in a cast-iron box with a tight lid. The sides of the box must be at least $\frac{3}{8}$ in. thick, and at least a thickness of $\frac{1}{2}$ in. of pure iron-filings should cover or surround the cast-steel surface to be decarbonated. The box is allowed to cool very slowly, by shutting off all access of air to the furnace, and covering it with a layer of 6–7 in. of fine cinders.

Each side of the steel plate must be equally decarbonated, to prevent it from springing or warping in hardening. The safest way to heat the plates is to place them in a vertical position. The best steel is preferred to any other for the purpose of making plates, and more especially when such plates are intended to be decarbonated. The steel is decarbonated solely to render it sufficiently soft for receiving any impression intended to be made thereon; it is, therefore, necessary that, after a piece of steel has been so decarbonated, it should, previously to being printed from, be again carbonated, or reconverted into steel capable of being hardened. In order to effect this recarbonization, or reconversion into steel, the following process is employed. A quantity of leather is converted into charcoal, by exposing it to a red heat in an iron retort until most of the vaporizable matter is driven off. The charcoal is reduced to a very fine powder; a box made of cast-iron of sufficient dimensions to receive the plate which is to be reconverted into steel, so that the intermediate space between the sides of the box and the plate may be about 1 in., is filled with the powdered charcoal. Having covered it with a well-fitting lid, it is placed in a furnace similar to those used for melting brass, where the heat is gradually increased until the box is somewhat above a red heat; it is allowed to remain in that state till all the vaporizable matter is driven off from the charcoal. The lid is removed from the box, and the plate is immersed in the powdered charcoal, taking care to place it so that it may be surrounded on all sides by a stratum of the powder of a nearly uniform thickness. The lid being replaced, the box, with the plate, remains in the degree of heat before described for 3–4 hours, according to the thickness of the plate so exposed; 3 hours are sufficient for a plate ½ in. thick, and 5 hours when the steel is 1½ in. After the plate has been exposed to the fire for the proper length of time, it is taken from the box, and immediately plunged into cold water. It is found by experience that the plates, when plunged into cold water, are least liable to be warped or bent when they are held in a vertical position, and made to enter the water in the direction of their length. If a piece of steel, heated to a proper degree for hardening, be plunged into water, and suffered to remain there until it becomes cold, it is very liable to crack or break, and, in many cases, it would be found too hard for the purposes for which it was intended. If the steel cracks, it is spoiled. Therefore, to fit it for use, should it not be broken in hardening, it is the common practice to heat the steel again, in order to reduce or lower its temper. The degree of heat to which it is now exposed determines the future degree of hardness, or temper, and this is indicated by a change of colour upon the surface of the steel. During this heating, a succession of shades is produced, from a very pale straw-colour to a very deep blue. It is found that, on plunging the steel into cold water, and allowing it to remain there no longer than is sufficient to lower the temperature of the steel to the same degree as that to which a piece of hard steel must be raised to temper it in the common way, it not only produces the same degree of hardness in the steel, but, what is of much more importance, almost entirely does away with the risk of its cracking. The proper temperature arrived at, after being plunged into cold water, can only be learned by actual observation, as the workman must be guided entirely by the kind of hissing noise which the heated steel produces in the water while cooling. From the moment of its first being plunged into the water, the varying sound will be observed; and it is at a certain tone, before the noise ceases, that the effect to be produced is known. As a guide, take a piece of steel which has already been hardened by remaining in the water till cold, and by the common method of again heating it, let it be brought to the pale-yellow or straw-colour, which indicates the desired temper of the steel plate to be hardened. By this experiment, as soon as the workman discovers the colour to be produced, he will be able to judge of the precise time at which the steel should be taken out. Immediately on withdrawing it from the water, the steel plate must be laid upon or held over a fire, and heated uniformly until its temperature is raised to that degree at which a smoke is perceived to arise from the surface of the steel plate after having been rubbed with tallow; the steel plate must then be again plunged into water, and kept there until the sound becomes somewhat weaker than before. It is taken out, heated a second time to the same degree as before, a third time plunged into water till the sound becomes again weaker than the last, exposed a third time to the fire as before, and for the last time returned into the water and cooled. After it is cooled, the surface of the steel plate is cleaned by heating it over the fire. The temper must be finally reduced by bringing on a brown, or such colour as may suit the purpose required. The engraving is effected by graving and etching like copper; for biting-in, a mixture of 1 part pyroligneous acid, 1 nitric acid, and 3 water is used; it is run off from the plate in less than a minute; the plate is rinsed in running water, and dried quickly. Stronger acid is used when a deeper tint is required.

Engraving Steel Cylinders.—A cylinder of very soft or decarbonized steel is made to roll, under great pressure, backward and forward on the hardened engraved plate, till the entire impression from the engraving is seen on the cylinder in alto-relievo. The cylinder is then hardened, and made to roll again backward and forward on a copper or soft steel plate, whereby a perfect facsimile of the original is produced of equal sharpness.

On Stone.—Lithography, or engraving on stone, depends upon the following principles:—

(1) The facility with which calcareous stones imbibe water; (2) the great disposition they have to adhere to resinous and oily substances; (3) and the affinity between oily and resinous substances, and their power of repelling water. Hence, when drawings are made on a polished surface of calcareous stone, with a resinous or oily medium, their adhesion is so great that only mechanical means can effect their separation; and while the other parts of the stone take up the water poured upon them, the resinous or oily parts repel it. When, therefore, a coloured oily or resinous substance is passed over a stone prepared in this manner, it will adhere to the drawings, but not to those parts of the stone which have been watered.

The Stones.—The stones used in lithography come principally from Germany, but it is said that the Bavarian quarries are exhausted of the best kind, and that the finest stones are now obtained from Bruniquel, Tarn, and Garonne, in France, and a somewhat inferior quality from Vigan. A bed of lithographic stone 12 yd. thick has recently been discovered at Longinowka, in Galicia.

Stones are prepared for chalk drawings by rubbing two together, with a little silver sand and water between them, taking care to sift the sand from large grains, by which the surface would be scratched. The upper stone is moved in small circles over the under one, till the surface of each is sufficiently even, when they are washed, and common yellow sand is substituted for the silver sand, and produces a finer grain. They are then again washed clean, and wiped dry. It will be found that the upper stone is always of a finer grain than the under one. To prepare stones for writing or ink drawings, they are rubbed with brown sand, washed, and rubbed with powdered pumice; the stones are again washed, and each polished separately with a fine piece of pumice, or water Ayr-stone. Chalk can never be used on stones prepared in this manner. The same process is followed in order to clean a stone that has already been used.

The Ink and Chalk.—Besides the inks described on p. 1172, the following may be used:—Tallow, 2 oz.; virgin wax, 2 oz.; shellac, 2 oz.; common soap, 2 oz.; lamp-black, ½ oz. The wax and tallow are first put in an iron saucepan with a cover, and heated till they ignite; whilst they are burning, the soap is thrown in in small pieces, one at a time, taking care that the first is melted before a second is put in. When all the soap is melted, the ingredients are allowed to continue burning till they are reduced one-third in volume. The shellac is now added, and as soon as it is melted, the flame is extinguished. It is often necessary in the course of the operation to extinguish the flame, and take the saucepan from the fire, to prevent the contents from boiling over; but if any parts are not completely melted, they must be dissolved over the fire without being again ignited. The black is next added. When it is completely mixed, the whole mass is poured out on a marble slab, and a heavy weight is laid upon it to render its texture fine. The utmost care and experience are required in the making both the ink and chalk. Sometimes it is not sufficiently burned, and, when mixed with water, appears slimy: it must then be remelted, and burned a little more. Sometimes it is too much burned, by which the greasy particles are more or less destroyed; in this case, it must be remelted, and a little more soap and wax be added. This ink is for writing or pen-drawing on the stone. The ink for transfers should have a little more wax in it. The chalk consists of 1½ oz. common soap, 2 oz. tallow, 2½ oz. virgin wax, 1 oz. shellac, ½ oz. lamp-black, mixed in the same way as the ink.

The Transfer.—Transfer-paper for lithographic purposes is made in the following way:—½ oz. gum tragacanth is dissolved in water, strained, and added to 1 oz. glue and ½ oz. gamboge; 4 oz. French chalk, ½ oz. old plaster of Paris, and 1 oz. starch are powdered, sifted through a fine sieve, and ground up with the gum, glue, and gamboge; sufficient water is then added to give an oily consistence, and the compound is brushed on to thin sized paper. The drawing or writing, made on the prepared side of the transfer paper, is wetted on the back, and placed, face downwards, on the stone, which must previously be slightly warmed, say to about 52° (125° F.). The stone is passed through the press four or five times; the paper is then damped, and carefully removed.

Drawing on the Stone.—The subject is first traced on the stone in red, great care being taken not to touch the stone with the fingers. Or the drawing may be done by means of a black pencil; but this is objectionable, as it is difficult to distinguish the line from that made by the chalk or ink. Then, having a rest to steady the hand, the drawing is gone over with the chalk, pressing it with sufficient firmness to make it adhere to the stone. For flat tints, considerable practice is necessary to secure an even appearance, which is only to be obtained by making a great many faint strokes over the required ground. Lights may either be left, or, if very fine, can be scraped through the chalk with a scraper. If any part is made too dark, the chalk must be picked off with a needle down to the required strength.

Preparing for Printing.—After the drawing on the stone has been executed, and is perfectly dry, a very weak solution of nitric acid (1 part in 100 of water) is poured upon the stone, which not only takes up the alkali from the chalk or ink, as the case may be, leaving an insoluble substance behind it, but lowers, to a small extent, that part of the surface of the stone not drawn upon, thus preparing it to absorb water with greater freedom. Place the stone in a sloping position, then pour the solution over it, letting it run to and fro until it produces a slight effervescence. Then wash the stone with water, and afterwards pour weak gum-water over it. The acid, by destroying the alkali on the lithographic chalk, causes the stone to refuse the printing-ink except where touched by the chalk; the gum-water fills up the pores of the stone, and thus prevents the lines of the drawing from spreading. When the stone is drawn on with ink, there must be a little more acid used with the water than when the drawing is made with chalk. The roller charged with printing-ink is then passed over the stone, which must not be too wet, and the impression is taken by passing through a press, in the usual manner, the processes of watering and inking being repeated for every impression. If the work is inclined to get smutty, a little vinegar or stale beer should be put into the water that is used to damp the stone.

Engraving on Stone.—The stone must be highly polished. Pour the solution of aquafortis and water over it, washing it off at once. When dry, cover with gum-water and lamp-black; let this dry, then etch with a needle, as on copper. It is necessary to cut the surface of the stone through the gum, the distinction of light and dark lines being obtained by the use of fine- and broad-pointed needles. Rub all over with linseed-oil, and wash the gum off with water. The lines on the stone will appear thicker than they will print.

To Imitate Woodcuts on Stone.—Cover with ink those parts meant to be black; scratch out the lights with an etching-needle; the lines which come against a white background are best laid on with a very fine brush and lithographic ink.

To remove a Transfer.—The existing transfer is ground away by rubbing it with another piece of stone, putting sand between, using finer sand as it gradually wears away; then it is ground with rotten-stone, till of the requisite fineness for the next transfer.

Transferring from Copper to Stone.—In transferring from copper to stone, use is made of prepared paper, that is, ordinary unsized paper, coated with a paste of starch, gum arabic, and alum. About 60 parts of starch are mixed with water to a thinnish consistency over a fire; have 20 parts of gum ready dissolved, and also 10 parts of alum dissolved; when the starch is well mixed, put in the gum and alum. While still hot, coat the paper with it in very even layers; dry, and smooth out. Take an impression from the copper with the transfer-ink; lay the paper on the stone, damp the back thoroughly with a sponge and water, and pass through the lithographic press. If all is right, the impression will be found transferred to the stone, but it will, of course, require preparing in the usual manner. The great advantage gained is, that very many more impressions may be printed from stone than from a copper plate, and very much more quickly.

On Zinc.—Zincography differs only in a few details from lithography. All ordinary drawings may be made on zinc plates instead of stone, the materials and mode of printing being the same. The plates compete successfully with large stones on the scores of price and portability. The zinc employed is of the quality known as "best rolled vieille montagne." Irregularity of surface may be remedied by pressing. The coating of scale and oxide is removed by scraping, and the surface is then rubbed with pumice, &c., exactly like stone. All drawings on zinc are made on a grained surface, which is produced as in the case of stone, replacing the stone muller by one of zinc. When grained, the plate is washed first with cold and then with hot water, and dried rapidly. A once-used plate may be re-prepared by removing the ink by spirit of turpentine, washing first with water and then with strong alkali, pouring over a mixture of 1 part each sulphuric and hydrochloric acids in 24 parts water, washing again with water, and re-graining.

The drawing is made as on stone, and etching is then effected by one of the following mixtures:—(*a*) ¾ pint of decoction of nut-galls, made by steeping 4 oz. in 3 qt. water for 24 hours, boiling up, and straining; ¼ pint gum solution, of creamy consistence; 3 dr. solution of phosphoric acid; (*b*) 1¼ oz. nut-galls boiled in 1¼ lb. water till reduced to ⅓, strained, and added to 2 dr. nitric acid and 4 drops acetic; (*c*) decoction of nut-galls simply. After etching, the sequence of operations is washing off; gumming in; drying by heat; washing off with turpentine, without moistening or removing the gum; rolling in till quite black; sprinkling with water, and continuing to roll and sprinkle till the plate is clean and the work is rolled up. Printing is performed as with stone, using an ink containing weaker varnish, and exercising somewhat greater precaution.

Photographic Processes.—Since the modern development of photography (see Photography, pp. 1532–44), a great number of printing processes, some remarkably simple, others more intricate, and many bearing a close general resemblance to each other, have been devised. These will now be noticed.

Willis's Aniline.—The process of W. Willis is founded on the action of bichromates on organic matter, the printed image being coloured by means of an aniline salt; it is extremely useful for copying plans and simple line-subjects. The operation is as follows:—Sized paper is floated in potassium bichromate containing a little phosphoric acid; it is next exposed beneath a translucent positive, and when the image of the latter is clearly shown, it is subjected to the action of aniline vapour. The result is that the parts shielded from the light by the lines of the positive are deeply coloured (green, black, or reddish, according to the aniline salt used), while the other parts retain the weak tint of the reduced chromium oxide. In developing the print, it is exposed to the contact of the vapour from aniline dissolved in spirit of wine, the solution being placed in a basin, and heated by a spirit-lamp. The prints are fairly permanent after washing.

Poitevin's Powder.—A mixture of gum arabic, sugar, and glycerine, with some sensitizing solution of potassium bichromate, is poured upon an impervious surface (e. g. a glass plate), and dried by warmth. Thus prepared, the plate is immediately exposed beneath a translucent positive for a few minutes. The parts affected by the light become hygroscopic, in proportion to the duration of the exposure, and intensity of the light, and any impalpable powder delicately brushed over the plate will adhere to the hygroscopic parts, according to their degree of moisture, thus forming a reversed copy. The developed image is coated with collodion, and transferred to paper unreversed, the soluble bichromate being washed out in the operation. Obernetter's recipe for the sensitizing solution is:—4 parts dextrine, 5 parts white sugar, 2 parts ammonium bichromate, 2–8 drops glycerine for every 100 *cc.* of water, and 96 parts water. The glass plate is sometimes previously coated with collodion.

Herschel's Cyanotype.—This process is in very common use by architects and engineers for copying plans, producing an image with white lines upon a blue ground. Sensitive paper is made by brushing it over with a solution of ferric oxalate (10 gr. to the oz.); it will remain good for years, if kept secure from light. The sensitive paper is exposed under the positive, and then brushed over with, or immersed in, a solution of potassium ferricyanide (red prussiate of potash), of almost any strength, by which the image is developed. The colour of the ground is deepened by subsequent washing with solution of potassium bisulphate. The ferric oxalate (peroxalate of iron) is prepared by saturating a hot aqueous solution of oxalic acid with ferric oxide (peroxide of iron). A better sensitizing solution may be prepared by mixing 437 gr. ammonium oxalate, 386 gr. oxalic acid, and 6 oz. water, heating to the boiling-point, and stirring in as much hydrated peroxide of iron as it will dissolve.

Pellet's—Pellet's process, which gives copies in blue lines on a white ground, is an improvement upon the white lines on blue ground, as a method of obtaining copies of drawings, inasmuch as it permits the subsequent tinting of the copies, and requires much shorter exposure. The original drawing is placed in a printing-frame, in front of a corresponding sheet of the sensitive paper (supplied by the inventor), composed of a piece of stout paper, coated with a mixture of perchloride of iron and some easily oxidizable organic substance. The frame being exposed for a minute in the sunshine, the per-salt of iron becomes reduced to a proto-salt wherever the sensitive paper is unprotected by the opaque lines of the original drawing. On removal from the frame, the exposed sheet is immersed in a strong solution of potassium ferrocyanide, and this substance, reacting with the per-salt of iron remaining on those parts of the paper protected by the opaque lines, produces Prussian blue, while the ground of the paper remains white. The print is washed, soaked in dilute hydrochloric acid, and washed again to remove traces of the acid.

Woodbury-type.—Woodbury's process is intended to produce a mould of a gelatine print, from which, other prints may be obtained. A thick film of sensitive gelatine, resting on a tough stratum of collodion, is placed beneath a negative with the collodion side next the image. After sufficient exposure to a light so arranged that the rays always fall in one direction, the gelatine picture is developed as if it were an autotype print, and presents the image in considerable relief. After drying, it is laid on a perfectly flat metallic plate, and a sheet of lead or some other soft metal is forced down upon it by a powerful press. The metallic sheet, being an exact mould of the gelatine picture, is put into a special press; and a viscous compound of gelatine dissolved in hot water, with the addition of fine pigment or permanent dye, is poured upon this sheet. Strongly-sized paper, of even texture, is placed upon the viscous compound, and the top plate of the press is brought down upon the mould, and firmly held, thus squeezing out the superfluous gelatine. The gelatine soon sets, when the top is raised, and the paper bearing the picture is detached. The print is immersed in alum solution, to render the impression insoluble. The top plate of the press is made of thick glass, and its surface is a perfect plane, to ensure the gelatine being squeezed out from the portions which are to be white in the picture, and to prevent a mottled and uneven appearance. Within certain limits concerning the size of white surface which can be produced (owing to the variations in the thickness of all paper), this process is capable of producing permanent images at a price but little greater than the cost of the paper and solution.

Photo-lithography.—Another process founded on the insolubility of gelatine when treated with a bichromate and exposed to light, is one capable of producing pictures in printing-ink, as well as in ink adapted to transferring to zinc or stone, images being reproduced by ordinary surface-printing from the transferred prints. The photographic negative is placed in a photographic printing- or pressure-frame, with a piece of prepared paper face downwards upon the picture side of the glass. The back is made secure, and the glass side is exposed to the light; in due time, it is taken to the dark-room, and coated with transfer-ink. Washing removes the transfer-ink from those parts which have not been affected by the light (the white parts of the paper), but leaves it where the light has acted (the lines of the picture); thus a photographic transfer is produced, and may be applied to stone or zinc, and printed from in the usual manner. The sensitizing solution is prepared as follows:—1–1½ oz. of gelatine (the smaller quantity if "flake") is set to soak in sufficient water to cover it; meantime, 1 oz. potassium bichromate is dissolved in 5 oz. water, and filtered; when the gelatine has plimmed, pour on sufficient boiling water to make 11 oz., and add the bichromate solution. Sometimes a dash of glycerine is added. This solution will keep good for a considerable time in a cool place. To prepare the paper, some of the solution is warmed to about 38° (100° F.), and sheets of the paper ("bank post," "positive photographic," or other fine-wove and slightly sized) are floated on it for 2–3 minutes, and hung up to dry in the dark-room, then again floated, and suspended from the opposite end. The sensitized paper is exposed in the ordinary manner beneath a negative in the pressure-frame, until the lines appear of a fawn-colour on a yellow ground.

The picture is transferred to stone or zinc by coating the latter with ink, laying the former face downwards upon it, and pulling through the press. Ordinary chalk lithographic ink may be used for single prints, but a superior ink is made as follows:—16 oz. lithographic ink and 8 oz. middle linseed varnish are first mulled together; 6 oz. Burgundy pitch and 2 oz. bitumen are melted over a clear fire till all the water is driven off; 1 oz. white wax is also melted; the whole is then mixed together, with 1 oz. palm-oil, and run into vessels for keeping. The print is developed by being floated back downwards on water at a temperature of 38°–50° (100°–122° F.), till the lines appear as depressions. It is then washed with water at about 70° (158° F.) on an inclined slab, by which, the soluble gelatine is removed with the ink that coated it, and the image remains as ink lines on ridges of insoluble gelatine. The developed print is washed in cold water, and hung up to dry; it is then ready for transferring to stone or zinc, being first damped till it becomes limp. The subsequent manipulation is a mere repetition of lithographic printing (see p. 1615).

Relief and Photo-engraving Processes.—Relief processes are those which produce plates or blocks with raised lines, capable of being printed from like type in an ordinary printing-press. They are adapted only to line drawings, and are unsuited for the reproduction of toned work. Engraved plates have the lines of the original drawing in depression, and are adapted to the same class of work as relief processes. Both are produced by the same general method and on the same principle, of which, the following is an outline. The foundation of the system is the fact that asphalt or bitumen, when exposed to light, becomes insoluble in its ordinary solvents if partially saturated. In Niépce's process, the first based on this ground, silver plates were coated with bitumen, the unaltered portions of which were dissolved away after exposure; iodine was applied, the remaining bitumen was removed, and the result was a metallic silver image on a ground of silver iodide. The solvent generally employed is chloroform. The coated plate is dried, and exposed beneath a subject. The portions to be protected from the influence of the light will depend upon whether the plate is to be engraved or in relief; in the former case, the lines will need protection. Care must be taken that the opacity, where required, is perfect. For engraved plates, a reversed positive is necessary; for relief blocks, an ordinary unreversed negative. The original picture is placed in contact with the prepared plate, and exposed as long as is considered necessary; the soluble portions of the bitumen are then removed by a nearly saturated solvent, leaving the metal bare. This latter may be zinc, copper, or steel; the first is most commonly used for relief blocks, while the two last are more convenient for engraving. The "biting-in," or development of the lines, is effected, in the case of zinc, by simple hydrochloric acid, though it is advisable to previously dip the plate in a sulphate of copper solution; for copper and steel, a mixture of hydrochloric acid and potassium chlorate is preferred. With relief blocks, the biting-in is a tedious operation, having to be carried as deep as in a wood-block. After the first biting, which gives the clear lines, the plate is heated, dusted over with rosin, and reheated to make the bitumen quit the lines, these operations being repeated till sufficient depth is attained. In appreciably large spaces, the metal is removed by engravers' tools.

Ehrard's biting-in process differs somewhat from the preceding. A transfer is prepared as for zincography, transferred to a copper plate, and plunged into an electro-plating bath for a few minutes, thus coating the copper with a thin silver film, while the lines are protected by the greasy ink; the plate is rinsed in dilute acid, and placed in a mercuric chloride bath, where a double chloride is formed; after washing, and removal of the ink, the biting-in proceeds.

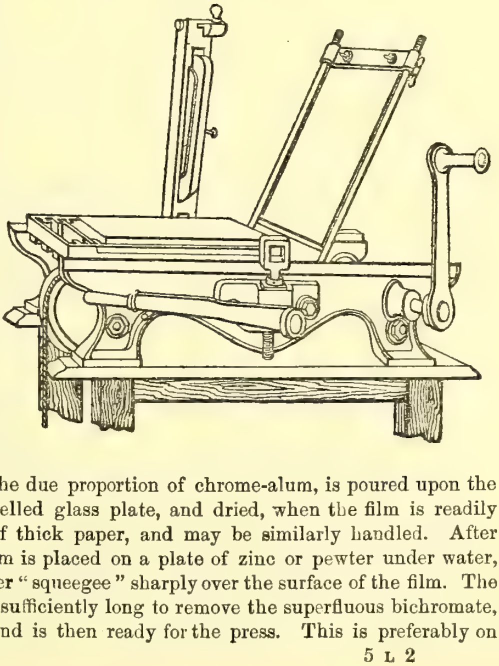
Fox Talbot proposed a modification, which consisted in printing the negative on a gelatine film, washing away the unaltered gelatine, and making an electrotype. Scamoni has some plan of building up a relief on the negative itself, and taking an electrotype from it. The foregoing methods, with perhaps some other modifications, are in extensive use on an industrial scale. Several firms are largely engaged in making relief blocks and photo-engravings, notably Leitch, Dallas, and Cattell, in London, besides many others on the Continent and in America. The illustrations in this Encyclopædia have been prepared by the first-named firm, from drawings on stone by B. Alexander, Castle Street, Holborn.

Much has been done in the more difficult task of reproducing half-tone drawings and photographs from nature, by Woodbury, Dallas, Lenoir, and others. A manager of Goupil's, named Roussillon, availing himself of the Woodbury-type process (see p. 1617), gives a grain to the picture by the action of light, suitably regulated, and thus obtains a mould capable of giving mezzo-tints from ordinary negatives. They require some mechanical touching-up, however. Lenoir has recently made public a new process for producing engraved plates from negatives photographed from nature, which is substantially as follows. A metallic plate is lightly coated with a mixture of albumen, carmine, and potassium bichromate. The carmine (for which, gamboge and various resins may be substituted with almost equal success) serves both as a dye and to assist in the lifting of the film, by its solubility in ammonia, drawing the albumen with it more or less in the stripping-off, the exposure having taken place upon the upper surface. When the film is stripped off, an image remains formed of albumen, in itself unable to resist the action of acids. It must, therefore, be rendered insoluble. There are two ways by which this may be effected; one is to cause the albumen to absorb a solution of gum lac, dissolved in hot water with borax; the other, and preferable, is to plunge the plate, once stripped, in a solution of potassium bichromate, then drying at about 49° (120° F.). The albumen by this means acquires the required resistance to the action of acids. The plate is next engraved, to give it a grain according to the amount of ink it should take up. Upon the unabsorbent and stripped plate, a film is spread, consisting of a solution of bitumen and turpentine mixed with carbonate of lime. When plunged in an acid bath, carbonic acid is liberated; it forms tiny canals, through which, the acid attacks the metal more or less quickly, by reason of the thickness of the albumen. The acid bath is composed of water acidulated with nitric and oxalic acids and alum. An oxalate of the metal is thus formed on the sides of the canals, and causes them to adhere to the plate. The texture of the etching is more or less fine according to the length of time the albumen is allowed to absorb the acid. In this state, the plate is finished; it requires only to be dried, and is ready to be printed from immediately. No preliminary preparation is necessary, as the whole operation may be conducted in three hours.

Warnerke has recently published some improvements based upon the discovery that a gelatine plate submitted to pyrogallic acid becomes insoluble in the parts exposed to light. The ordinary gelatine process requires very accurately-timed exposure; but with the pyrogallic acid, and using the emulsion on paper, no amount of over-exposure will do harm, provided the developer is sufficiently restrained. The transfer of the image from the paper to glass is very simple. The former is immersed in water, and placed in contact with a glass plate; the superfluous moisture is removed by a squeegee, and the paper is stripped off, leaving the gelatine on the glass, when the application of hot water dissolves all the gelatine not acted upon by the light, and the image is left in relief on the glass. Intensification is effected by mixing with the emulsion a non-actinic colouring matter which is not affected by silver; aniline colours answer the purpose well. Relief is said to be obtained far more easily than by the ordinary bichromatized gelatine, and the process is therefore specially applicable to Woodbury-type. It may also be adapted to engraving, enamelling, and collotype purposes.

Collotype Processes. — Several methods of collotype printing have been described under Photography (p. 1543). Impressions may be obtained in a lithographic press, but the form shown in Fig. 1169 is especially adapted to this process.

1169.



Edwards' Heliotype.—The most important of the many modifications of the collotype process is the "heliotype" invented by Ernest Edwards, wherein the great advantage consists in toughening the gelatine film by means of chrome-alum. His method is briefly as follows:—The solution of gelatine and bichromate, with the due proportion of chrome-alum, is poured upon the previously waxed surface of a carefully levelled glass plate, and dried, when the film is readily detached. The latter resembles a piece of thick paper, and may be similarly handled. After exposure in contact with a negative, the film is placed on a plate of zinc or pewter under water, and firmly attached by passing an indiarubber "squeegee" sharply over the surface of the film. The printing film on its plate is soaked in water sufficiently long to remove the superfluous bichromate, to prevent the further action of the light, and is then ready for the press. This is preferably on the vertical principle, such as the Albion printing-press. The inking possesses peculiar features a very stiff ink may be used to give the deepest shadows, and this may be followed by a thinner ink, even one more or less coloured, for the half-tones, thus producing a bichromatic effect in a single printing. The time occupied in drying the film is 24–36 hours at 32° (90° F.); 1500 copies have been successfully taken from one plate; one man can print 200–300 copies daily; for very long numbers, it can hardly compete with lithography in price, but for moderate numbers, the cost is very small.

Capt. Waterhouse has introduced a modified process, as follows:—The sensitive film is laid on flat copper plates, finely grained on one side. After levelling on the drying-apparatus, the plates are washed with warm water, and coated on the grained side, while still wet, with a mixture of 15 *grm.* Nelson's opaque gelatine, and 4 *grm.* powdered potassium bichromate, in 100 *cc.* water, adding 4 *cc.* formic acid when the first are dissolved. This is applied like collodion, and the excess is poured off. The coated plates are replaced in the drying-apparatus, and covered over. In about 2 hours at 50° (122° F.), the films dry with a fine, even, glossy surface, perfectly free from streaks and waviness. It is best to let the plates harden for a day or two before use.

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(See Ink; Photography.)

RESINOUS AND GUMMY SUBSTANCES (Fr., *Matières Résineuses et Gommeuses*; Ger., *Harz- und Gummi-arten*).

Resinous and gummy substances may be primarily divided into three great classes—gums, resins, and indiarubbers; each of these classes may be split into a number of sub-sections.

1. Gums.—The term "gum" is properly restricted to those exudations from the stems, branches, and fruits of plants, which dissolve or soften in water to a slimy liquid state, or at least to a gelatinous consistency; which refuse to dissolve in alcohol of 60 per cent.; which yield mucic and oxalic acids when treated with nitric acid; and which are capable of conversion (by sulphuric acid) first into dextrine and then into sugar. The form, surface, colour, transparency, density, microscopic characteristics, and optical properties scarcely admit of any generalization, and will best be noticed under the individual substances. As to the chemical constitution of gums, all natural vegetable gums (thus excluding dextrine) are substantially composed of one or more of the three bodies—bassorine, arabine, and cerasine. Bassorine is a pure hydrocarbon; arabine and cerasine are hydrocarbons combined with mineral bases. Bassorine is devoid of colour, odour, and flavour; it is insoluble in water and alcohol, but heated in the former, assumes a gelatinous character; dried at 100° (212° F.), its formula is $C_6H_{10}O_5$. Arabine is a compound of arabic acid with lime and some potash or magnesia; it is a colourless, odourless body, of acid reaction, forming with water a glutinous, frothy solution; on burning, it leaves an ash consisting chiefly of carbonate of lime, but containing also some carbonate of potash. Arabic acid is a white substance, soluble in water, and reddening litmus; its solution dries to a colourless, amorphous body; dried at 100° (212° F.), its formula is $C_{12}H_{22}O_{11}$. Cerasine is a colourless body, insoluble in water and alcohol, but, like bassorine, swelling in the former to a kind of gelatine; it is a compound of metagummic acid and lime. Natural gums also contain water (12–17 per cent.), dextrine, sugar, tannin, colouring matter, and mineral ingredients; they afford 2–3 per cent. of ash.

Concerning the origin of gums. They were formerly supposed to be secretions of plants; recent researches, however, have clearly proved that at least some gums are formed from the whole tissue of the cell-walls, by chemical metamorphosis. This is considered certain in the case of tragacanth, cherry, and arabic gums. [The reader is referred to some special remarks on tragacanth under that head, pp. 1685–6.] Wiesner holds the same view with regard to moringa and

Indian tragacanth (kuteera) gums. Accordingly it happens that gums are yielded most abundantly when the plants are in a sickly state, caused by a fulness of sap in the young tissues, whereby the new cells are softened and finally decomposed; the cavities thus formed fill with liquid, which exudes, dries, and constitutes "gum," which, in structure, is quite amorphous, being neither crystallized nor organized. Gum is one of the most common plant-products. It occurs abundantly in the living rind of many plants, and exudes upon the surface of the bark. In the woody structure, it occurs more seldom, and in smaller quantity. The sources of the most important gums may be seen from the following synopsis:—

Mimoseæ.—Acacia spp., giving Arabic (including Senegal, Suakin or Talca, Morocco or Barbary, Cape, E. India, and Australia or Wattle), and Kuteera (Indian Tragacanth); *Prosopis spp.* (Mezquite); *Parkia spp.*

Papilionaceæ.—Astragalus spp. (Tragacanth).

Drupaceæ.—Prunus spp., and *Amygdalus spp.* (collectively Cherry gum).

Anacardiaceæ.—Anacardium occidentale (Cadjii); *Spondia spp.; Odina spp.* (Ging and Kunnee); *Rhus Metopium.*

Aurantiaceæ.—Feronia elephantum (Wood-apple).

Meliaceæ.—Melia Azedarach.

Ternströmiaceæ.—Cochlospermum gossypium (Kuteera [Indian Tragacanth]).

Bombaceæ.—Adansonia digitata.

Sterculiaceæ.—Bombax spp.; Sterculia spp. (contributing to Kuteera).

Cactaceæ.—Cactus spp.; Opuntia spp.

Moringaceæ.—Moringa pterygosperma (Moringa).

Bromeliaceæ.—Puya spp. (Chagual).

Palmaceæ.—Cocos nucifera (Coco-nut).

Gums may be divided into the following four classes:—

(1) Arabinic.—These consist essentially of arabine; cerasine and bassorine are either quite absent, or in very minute proportion. The chief are—Arabic (all kinds), Wood-apple, and Cadjii gums.

(2) Cerasinic.—Contain varying proportions of cerasine and arabine. The Cherry group.

(3) Bassorinic.—Essentially composed of bassorine. Embraces Tragacanth, Kuteera, Coco-nut, Chagual, and Moringa gums.

(4) Cerasino-bassorinic.—Compounded of cerasine and bassorine. Kuteera (some kinds).

2. Resins.—Under the term "resins," are included all the hard, friable, natural plant-substances, externally resembling gums; insoluble in water; soluble in ether and alcohol; rich in carbon; poor in oxygen; free from nitrogen; and burning with a smoky flame. No resin is a definite chemical compound, but rather a complicated mixture. The essential ingredients of resins are the resin-acids—substances rich in carbon; some of them displace the carbonic acid in alkaline carbonates, and form with the alkalies the so-called resin-soaps, which froth in water. Besides the resin-acids, natural resins contain volatile oils, gums, and often cinnamic and benzoic acids, as well as the ordinary components of plant-tissues—cellulose, tannin, humic bodies.

The older chemists classified resins into "hard," "soft," and "feather." The two first are now combined as "resins" simply, their difference in hardness being only a matter of degree, while most of the soft resins become hard in time. "Feather" resins denoted indiarubbers, which are now excluded from the resins altogether, on the ground of both physical and chemical dissimilarities, and will receive a separate description. The usual classification now adopted by Continental chemists is threefold:—(1) True resins, (2) gum-resins, (3) balsams. The gum-resins differ from true resins only in containing some gum. Balsams include both resins which are rich in volatile oil, the latter assuming a resinous character, or holding a great portion of the resin in solution, thus forming a syrupy mass (such as turpentine and Canada balsam); and bodies which in outward character resemble the resinous balsams (like Peru), and are chemically poor in resinous matters, though rich in a fluid neutral substance bearing some likeness to certain resins. The classification adopted by M. C. Cooke differs considerably from the foregoing. Omitting the gums, which have been already dealt with, he forms three groups—gum-resins, resins, and oleo-resins. The gum-resins embrace three classes—emulsive, fetid, and fragrant, the last being again sub-divided into sections, represented respectively by bdellium and benzoin. The true resins he distinguishes as hard or copalline (sub-classified as pale and dark), and soft or elemi. While his oleo-resins embrace balsams, natural varnishes, and turpentines and tars (the two last grouped together). Usually in England, however, the term gum-resin is applied to an inspissated milky plant-juice, consisting of a gum soluble in water, associated with a resin and a volatile oil soluble in alcohol, and containing other vegetable and a little mineral matter. The general acceptation of the term "balsam" is an oleo-resin, or natural compound of a resin and an essential oil, in such proportions as to form a viscous or semifluid mass. From the solid resin to the limpid essential oil are insensible gradations, and few resins are hard at the moment of their exudation. The proposal to confine the term balsam to such bodies as contain cinnamic (or an analogous) acid, in addition to the resin and essential oil composing the oleo-resin, has not been carried out; but the fragrant balsams containing cinnamic or benzoic acids are regarded as a distinct class by authorities on materia medica, though Cooke includes under the term all the oleo-resins, except the natural varnishes (acrid lacquers) and the turpentines and tars.

Of the physical characteristics of the resins generally, the first to be considered are their form and size. The hard resins have a drop-like, stalactitic, or knotty form. When the resin spreads over the surface of the plant and there collects, it is usually drop-like or stalactitic; when it flows into the ground, it becomes knotty. Other forms are rare. The drops, as met with in commerce, are generally pretty constant in shape for each kind, but the stalactitic and knotty form vary much in that respect. Some commercial resins are shaped by artificial means—dragon's-blood in sticks or tears, gamboge in cylinders, shellac in laminæ.

The surface of many resins forms an important characteristic. In red xanthorrhœa, the surface which was in contact with the stem is rough, dull, unresinified, and possesses structural peculiarities that will be detailed when speaking of it in particular. Many resin-surfaces present polygonal excrescences, with regular crystallographic form. In Zanzibar copal, these are visible by the naked eye; and in sandarach, by the aid of a glass.

Resins seldom present a definite structure, as they occur for the most part in thick homogenous masses. But benzoin, yellow xanthorrhœa, and the softer kinds of dragon's-blood exhibit a structure known as amygdaloidal to mineralogists. It is produced by a number of rounded grains imbedded in the mass, and differing from it in colour. Some sorts of turpentine-resin are permeated by globular pores of various size.

Most resins are quite amorphous; few contain crystalline substances, and still fewer occur as crystals themselves. The turpentines often hold abietic acid in the form of crystals. In the turpentine-resins, a crystalline body is frequently visible. In the elemi-resins, which are very rich in crystalline components, it often happens that the optical properties of the mass so nearly approach those of the crystals, that the latter only become visible after dissolving the amorphous portion in alcohol.

The optical properties of the resins seldom afford any guide.

The colours of the resins are in many cases pronounced, as the yellowish-brown of gamboge, the red of dragon's-blood and red xanthorrhœa, the white of Siam benzoin, and the black of some rosins. Many resins are colourless; the tints of most lie between yellow and brown.

In transparency, the resins vary much. Some are as transparent as glass (certain copals); others are quite opaque (xanthorrhœa, dragon's-blood). Most are merely translucent to the naked eye. Microscopic sections, even of the quite opaque, are at least translucent, and often communicate their own colour to the transmitted light.

The lustre of most resins is almost adamantine, and constitutes a degree termed "resinous" by mineralogists. There also occur those of fatty (small sorts of benzoin, and dragon's-blood) and of waxy (the "almonds" of benzoin) lustres, and some are lustreless (certain elemi-resins).

The fracture is mostly glassy, often conchoidal; sometimes also smooth, granular, earthy, and splintery.

The hardness of most resins lies between gypsum and rock salt; only the best copals are harder than the latter, and for the verification of these, hardness is one of the best tests.

The density (sp. gr.) is for many resins a distinctive feature, e. g. many copals. In general, the sp. gr. of resins is somewhat greater than that of water, while the gum-resins are considerably heavier, e. g. asafœtida 1·3. The balsams are mostly lighter than water. The specific gravities of some of the resins are shown in the annexed table:—

Table of Specific Gravities of Resins at 15°–16° (60° F.).

Pine-rosin, yellow transparent	1·083–1·084
„ whitish opaque ..	1·044–1·047
„ dark colophony ..	1·100
Shellac, light coloured	1·113–1·114
„ darker	1·123
„ bleached	0·965–0·968
Dammar, old	1·075
Copal, E. Indian	1·063–1·070
„ W. Indian	1·070–1·800
Copal, very old	1·054–1·055
Benzoin, Siam	1·235
„ Penang	1·145–1·155
„ Borneo	1·165–1·170
Guaiacum, pure	1·236–1·237
Amber	1·074–1·094
Sandarach	1·038–1·044
Mastic	1·056–1·060
Tolu, old brittle	1·231–1·232

In tenacity, most resins are friable; some are soft (stick-lac, shellac), some pliant (elemi). The degree of friability can be tested by scratching the surface with a needle: the most friable show a splintery scar; the least, a smooth line.

Many resins, both coloured and colourless, give a white streak, even the dark-hued colophony. Some resins, finely disseminated through water, exhibit a rapid molecular movement; others a very indolent one. The most pronounced occurs in the case of gamboge; copal powder, on the other hand, moves very slowly.

Several resins possess highly characteristic odour and flavour.

The secretion or imprisonment of organic débris in resins is much more frequent than is commonly supposed. The fragments are mostly invisible, except through the microscope, and chiefly consist of particles of bark and wood from the stems of the plants, which have become imbedded during the concretion of the resin. The recognition of these remains in a resin is often of importance, the more or less decomposed tissue illustrating the characteristics of the resin, as well as indicating its origin and derivation.

Many resins, and at least all produced by the metamorphosis of the cell-tissues, contain also tissue-remains (e. g. dragon's-blood, xanthorrhœa). These are the more valuable according as the metamorphosis has been more complete. Red xanthorrhœa often shows pieces of tissue between the resinified masses. Organic remains not derived from the resin-forming organs of the plant also occur; e. g. fungi. Thus the fine green crust which coats old specimens of gamboge is due to a delicate mycelium fungus.

The microscopic examination of resins at once reveals some facts concerning their origin. While the structure of red xanthorrhœa, exhibiting all stages from unresinified to completely resinified tissue (according to Wiesner), indicates that this resin is solely due to chemical metamorphosis of the whole tissue, the microscope shows that gamboge must exist in solution in the tissue of the plant-stem, and consequently proceeds from a cellular secretion. Gamboge really consists of a gummy groundwork permeated by microscopic grains of resin. On cutting the gamboge tree, the resin-holding sap escapes, and mingles with the watery sap of other tissues, and thus occurs the secretion of the hard resin.

Dragon's-blood originates much in the same manner as xanthorrhœa; and according to the researches of Karston and Wigand, it is probable that the ordinary resins of the *Coniferæ* (rosins) are produced in the same way. But it must not be supposed that the metamorphosis from the cellulose of the cell-walls to the resin is simple and direct. It is indirectly evident that the cell-walls of the resinified tissue, before their complete conversion into resin, yield a quantity of tannin. This tannin seems to be a medium between the hydrocarbon and the resin. In the resinification of whole tissue, it is doubtless not only the cell-membrane, but also more or less of the cell-contents, that is utilized. When a resin, like mastic, occurs in ready-formed veins, and is not produced by the resorption of cells or whole tissue, it must be considered as a secretion-product.

The melting-point is a characteristic test for different kinds of resin, and even for different grades of the same kind. The lowest met with is that of Siam benzoin—75° (167° F.); the highest, that of the hardest copals—360° (698° F.) The solubilities of the various resins in such solvents as alcohol, ether, carbon bisulphide, turpentine-oil, cajuput-oil, chloroform, &c., are well-known guides to their identification (see pp. 1624–7).

The resins exhibit no such chemical relationship as do the fats, for instance. Some few show a general resemblance, e. g. mastic, sandarach, dammar, olibanum; but the greater number are not only dissimilar, but do not even admit of being grouped under sections. Resins are as a rule very complicated bodies, and their origin, as previously explained, makes it difficult to expect otherwise. The classification of resins according to the effects of simple reagents is impossible, and recourse has been had to oxidation with caustic alkali, with or without dry distillation. Hlasiwetz has proved in some resins a family relationship with the aromatic series, which clearly indicates that many resins are derived from essential oils; indeed from the terpenes (e. g. turpentine-oil, lavender-oil), colophony-like resins can be produced by oxidation, and it is quite probable that the so-called terpene-resins exist in the plants as essential oils. The terpene-resins are weak, sometimes crystalline, acids. Nature affords them mixed with unaltered terpene, which may be distilled off with water. The terpene-free resin is odourless, hard, and but little changed by caustic alkali. Many aldehydes are converted into resins by oxidation; acryl-resin and the resin of acetic aldehyde are familiar examples.

That resins are among the most widely-distributed plant-products, is well known. They are found in almost all forms of vegetable life, even in fungi. They chiefly occur in the bark, and either flow out over its surface, or aggregate within it. The chief resin-yielding plants are as follows:—

Leguminosæ.—Myrospermum spp. (Peru, Tolu); *Vouapa spp.; Copaifera spp.* (Copaiba).

Cæsalpiniæ.—Trachylobium spp., *Hymenæa spp.* (Copal, Jutahy-seca).

Anacardiaceæ.—Pistachia spp. (Mastic, Chian turpentine); *Rhus spp.*

Amyridaceæ.—Boswellia spp. (Frankincense, Olibanum); *Icica spp.* (Copal, Elemi); *Bursera spp.* (Elemi); *Canarium spp.* (Dammar); *Amyris spp.; Hedwigia balsamifera; Balsamodendron spp.* (Bdellium, Elemi, Myrrh, Balm of Gilead); *Elaphrium spp.*

Humiriaceæ.—Humirium spp.

Zygophyllaceæ.—Guaiacum officinale (Guaiacum).

Rhamnaceæ.—Zizyphus Jujuba (Lac).

Euphorbiaceæ.—Pedilanthus spp.; Euphorbium spp. (Euphorbium).

Dipterocarpæ.—Vateria indica (Piney); *Shorea spp.* (Dammar); *Hopea spp.* (Dammar); *Dryobalanops spp.* (Camphor); *Dipterocarpus spp.* (Gurjun); *Vatica sp.*

Combretaceæ.—Terminalia spp.

Bixineæ.—Lætia resinosa.

Guttiferæ.—Garcinia spp. (Gamboge); *Calophyllum spp.* (Tamanu and Tacamahaca); *Moronobea coccinea* (Hog).

Hyperiaceæ.—Vismia spp. (Gamboge).

Cistaceæ.—Cistus spp.

Hederaceæ.—Hedera helix.

Umbelliferæ.—Ferula spp. (Galbanum, Sagapenum); *Scorodosma fœtida, Narthex asafœtida* (Asafœtida); *Opoponax Chironium* (Opoponax); *Dorema ammoniacum* (Ammoniacum); *Thapsia garganica; Bolax spp.*

Rubiaceæ.—Gardenia spp. (Dika-mali).

Apocynaceæ.—Tabernæmontana utilis.

Asclepiadaceæ.—Cynanchum viminale.

Convolvulaceæ.—Convolvulus scammonia (Scammony); *Ipomœa purgans* (Jalap).

Compositæ.—Carlina gummifera; Ceradia furcata (Bdellium).

Styracaceæ.—Styrax spp. (Benzoin, Storax).

Artocarpaceæ.—Artocarpus integrifolia.

Moraceæ.—Ficus spp.

Altingiaceæ.—Liquidambar spp. (Storax).

Aquilariaceæ.—Aquilaria spp. (Lignum Aloes or Agar).

Betulaceæ.—Betula alba.

Coniferæ.—Abies spp., Pinus spp. (Rosin, Turpentines); *Araucaria spp.; Dammara spp.* (Copal, Dammar); *Callitris spp.* (Sandarach); *Juniperus communis.*

Liliaceæ.—Dracæna spp. (Dragon's-blood); *Xanthorrhœa spp.* (Xanthorrhœa).

Palmaceæ.—Dæmonorops spp. (Dragon's-blood).

Detection of Resins, Gum-resins, and Balsams.—The following scheme for the recognition of the more important resins, gum-resins, and balsams (oleo-resins) is due to Hirschsohn, whose researches in this direction are well known. The reagents employed are:—(1) Sulphuric acid, sp. gr. 1·820; (2) alcoholic hydrochloric acid, obtained by saturating 95-per-cent. alcohol with dry hydrochloric acid gas; (3) solution of 1 part bromine in 20 parts chloroform; (4) saturated solution of calcium chloride in distilled water at the ordinary temperature; (5) solution of 1 part perchloride of iron in 10 parts 95-per-cent. alcohol; (6) saturated solution of neutral lead acetate in 95-per-cent. alcohol; (7) solution of ammonia, sp. gr. 0·980; (8) solution of pure sodium carbonate crystals in distilled water; (9) Frohde's test: 1 *centigram* sodium molybdate in 1 *cc.* sulphuric acid; (10) impure chloral hydrate, containing alcoholate; (11) saturated solution of iodine in petroleum-spirit boiling at 60° (140° F.). The author's names have been retained: they sometimes differ from those adopted in this article, and it is not always apparent what precise product is intended in the absence of the botanical source, e. g. Borneo copal.

Completely soluble in Chloroform.

Completely soluble in Ether.

A. Ethereal solution becomes turbid after addition of alcohol.
  - I. Alcoholic solution gives with perchloride of iron a turbidity that disappears on boiling. Chloral reagent colours violet—*Canada Balsam.*
  - II. Alcoholic solution gives no turbidity with perchloride of iron.
    - 1. The drug is liquid and forms a clear mixture with petroleum-spirit boiling below 40° (104° F.).
      - *a.* Bromine solution colours the chloroform solution yellowish, then violet and blue—*Maranham Copaiba.*
      - *b.* Bromine solution produces no colour—*Para Copaiba.*
    - 2. The drug is solid, and dissolves only partially in petroleum-spirit. Iodine solution colours red-violet—*Ordinary Mastic.*

B. Ethereous solution forms clear mixture with alcohol.
  - I. Perfectly soluble in alcohol.
    - 1. Perchloride of iron colours the alcoholic solution blue.
      - *a.* Lead acetate gives a precipitate with alcoholic solution. Sulphuric acid dissolves the drug with a cherry-red colour—*Guaiacum.*
      - *b.* Lead acetate gives no precipitate. Sulphuric acid dissolves the drug with a yellow-brown colour—*Carana Resin* (*Aceyta americana*).

2. Perchloride of iron colours the alcoholic solution brownish or greenish.
a. Lead acetate gives with the alcoholic solution a precipitate that is not dissolved by boiling.
α. Sodium carbonate solution dissolves part at the ordinary temperature. Chloral test colours the evaporation-residue of a petroleum-spirit extract gradually red-violet with blue streaks—*Coniferous Rosins.*
β. Sodium carbonate dissolves none or a very small quantity.
i. Petroleum-spirit extract colourless. Chloral test produces no colour or a very faint greenish—*Bombay Mastic.*
Petroleum extract coloured.
ii. Dark-brown. Chloral test colours brown—*Mani Resin.*
iii. Yellow-brown. Chloral test colours gradually indistinct red-violet—*Carana Resin.*
iv. Yellow-brown. Chloral test and bromine solution colour a magnificent violet—*Carana hedionda.*
b. Lead acetate gives with the alcoholic solution a precipitate that dissolves on boiling.
α. Bromine solution colours red—*Peruvian Guaiacum.*
β. Bromine solution produces no coloration—*Alexandrian Mastic.*
c. Lead acetate gives no precipitate. Ammonia gives a turbid mixture—*Dragon's-blood.*
II. Imperfectly soluble in alcohol.
1. Lead acetate produces turbidity which disappears upon warming—*Brazilian Copaiba.*
2. Lead acetate gives no precipitate. The drug is clearly crystalline. Sodium carbonate does not dissolve it by boiling.
a. Bromine solution gradually colours green.
i. Alcoholic hydrochloric acid colours violet, blue, or brown—*Elemi.*
b. Bromine solution colours violet—*Elemi.*
c. Bromine solution produces no colour—*Elemi* (*Amyris elemifera*).

Imperfectly soluble in Ether.

A. Perfectly soluble in alcohol.
I. Sulphuric acid colours the evaporation-residue of a petroleum-spirit extract cherry-red. The drug is free from cinnamic acid—*Siam Benzoin.*
II. Sulphuric acid does not colour such residue, or only faintly light-brown. Contains cinnamic acid—*Sumatra Benzoin* or *Tolu Balsam.*
III. Sulphuric acid colours such residue yellow-brown passing into violet—*Black Peru Balsam.*
B. Imperfectly soluble in alcohol.
I. Perchloride of iron gives a precipitate, which is neither dissolved by boiling nor soluble in ether—*Brazilian Copal.*
II. Perchloride of iron produces no turbidity or only a slight one that disappears on boiling.
1. The ethereous solution gives with alcohol a turbid mixture.
a. Alcoholic hydrochloric acid colours it brownish. Chloral test colours evaporation-residue of petroleum-spirit extract greenish—*Dammar.*
b. Alcoholic hydrochloric acid colours it brick-red. Chloral test colours the petroleum-spirit residue carmine-red to violet—*White Peru Balsam.*
2. Ethereous solution gives with alcohol a clear mixture.
a. Ammonia gives with alcoholic solution a clear mixture. Bromine solution colours blue —*Ceradia Resin.*
b. Ammonia gives with the alcoholic solution a turbid mixture. Bromine solution colours greenish—*Mecca Balsam.*

Imperfectly Soluble or Insoluble in Chloroform.

Completely soluble in Ether.

A. Ethereous solution red. Ammonia gives with alcoholic solution a clear mixture—*Dragon's-blood from Pterocarpus Draco.*
B. Ethereous solution yellowish or colourless.
I. Alcoholic solution gives with lead acetate no precipitate—*Podocarpus Resin.*
II. Alcoholic solution gives with lead acetate a precipitate that is not dissolved by boiling—*Sandarach.*

Imperfectly soluble in Ether.

A. Ethereous solution becomes turbid after addition of alcohol.
I. Alcoholic solution gives with ammonia a clear mixture.
1. The mixture with ammonia is yellow. The solution of the resin in sulphuric acid is yellow-brown and gives with alcohol a clear violet mixture—*Eryops Resin.*
2. The mixture with ammonia is carmine-red—*Sonora Lac.*
II. Alcoholic solution gives with ammonia a turbid mixture.

1. Perchloride of iron colours green. The drug contains cinnamic acid. Lead acetate gives a precipitate—*Liquid Storax.*
2. Perchloride of iron colours brownish or not at all.
   a. The drug contains cinnamic acid, and gives with lead acetate no precipitate—*Liquidambar Balsam.*
   b. The drug contains no cinnamic acid, and gives with lead acetate a precipitate—*Euphorbia Tirucalli Resin.*

B. Ethereous solution gives with alcohol a clear mixture.
 I. Perfectly soluble in alcohol. Perchloride of iron colours dark-brown or black.
  1. Solution in alcohol is red.
   a. Lead acetate gives no precipitate. Chloroform extract colourless—*Xanthorrhœa quadrangularis Resin.*
   b. Lead acetate produces turbidity. Chloroform extract yellow—*Xanthorrhœa arborea Resin.*
  2. Alcoholic solution yellow. Lead acetate produces a precipitate—*Yellow Xanthorrhœa Resin.*
 II. Imperfectly soluble in alcohol.
  1. Alcoholic solution gives with ammonia a clear mixture.
   a. Ammoniacal mixture is violet. Lead acetate gives a violet precipitate—*Lac.*
   b. Ammoniacal mixture is yellow or colourless.
    α. Perchloride of iron colours the alcoholic extract black. Lead acetate gives no precipitate—*Gamboge.*
    β. Perchloride of iron gives a precipitate which is neither soluble in ether nor by heating. Lead acetate gives a precipitate.
     i. Readily and completely soluble in ether-alcohol.
     ii. Bromine solution precipitates the resin from the chloroform solution—*Australian Copal.*
     iii. Bromine solution produces no precipitate—*Manilla Copal.*
     iv. Imperfectly soluble in ether-alcohol—*E. Indian* and *African Copal.*
  2. The alcoholic solution gives with ammonia a turbid mixture.
   a. Perchloride of iron gives a precipitate that is neither dissolved by boiling nor in ether—*Borneo Copal.*
   b. Perchloride of iron gives no precipitate.
    α. Completely soluble in ether-alcohol. Chloral test colours evaporation-residue of petroleum-spirit extract blue to blue-violet—*Liquidambar styraciflua Balsam.*
    β. Incompletely soluble in ether-alcohol.
     † The drug contains sulphur.
      i. Yields umbelliferone by dry distillation.
      ii. Hydrochloric acid colours the evaporation-residue of the petroleum-spirit extract reddish-yellow; the chloral test colours it green—*Persian Sagapenum.*
      iii. Hydrochloric acid colours the residue blue-violet; chloral test colours it rose-colour to raspberry-red and violet—*Levant Sagapenum.*
      iv. Not coloured by hydrochloric acid. The solution of the drug in sulphuric acid is yellow-brown with a blue fluorescence. Potassium nitrate colours the gum-resin malachite-green—*Ordinary Asafœtida.*
      v. Yields no umbelliferone by dry distillation.
      vi. Sodium carbonate solution colours the drug light-brown, and the extract is not altered by acetic acid or lead acetate—*Asafœtida from Ferula alliacea.*
      vii. Sodium carbonate solution forms an emulsion that cannot be filtered.
      viii. Lead acetate gives no precipitate. Iodine solution is not altered—*Indian Bdellium.*
      ix. Lead acetate produces immediately or after a short time a precipitate that dissolves upon warming. Iodine solution is not altered—*African Bdellium.*
     †† The drug contains no sulphur.
      i. Yields umbelliferone by dry distillation.
      ii. The evaporation-residue of the petroleum-spirit extract is coloured by hydrochloric acid and the chloral test.
      iii. Hydrochloric acid colours reddish-yellow; the chloral test colours green—*Persian Galbanum.*
      iv. Hydrochloric acid colours red-violet; the chloral test colours greenish—*Levant Galbanum as at present in commerce.*
      v. Hydrochloric acid colours violet-blue; the chloral test carmine-red—*Older Specimens of Levant Galbanum.*
      vi. Hydrochloric acid gives no colour; the chloral test colours light-brown—*African Ammoniacum.*
      vii. Yields no umbelliferone by dry distillation.

viii. Chloride of lime solution colours the gum-resin orange-yellow—*Persian Ammoniacum.*
ix. Chloride of lime solution produces no colour. Lead acetate gives no precipitate.
x. Iodine solution is not altered; the chloral test colours greenish—*Olibanum.*
xi. Iodine solution is not altered; the chloral test gives no colour—*Indian Myrrh.*
xii. Chloride of lime solution produces no colour. Lead acetate gives a precipitate.
xiii. Bromine solution colours violet-red; the chloral test colours violet—*Ordinary Myrrh.*
xiv. Bromine solution produces no colour or only yellowish. Perchloride of iron colours green—*Opoponax.*
xv. Bromine solution produces no colour or only yellowish. Perchloride of iron colours brownish—*Euphorbium.*

INDIARUBBERS.—This group includes all plant-substances which, in physical characteristics, resemble or approach indiarubber. The physical properties of indiarubber are so remarkable and peculiar that it is difficult to mistake whether a plant belongs to this group or not. It comprises the various kinds of indiarubber, guttapercha, balata, &c. These products have hitherto been obtained exclusively from the milky saps of certain plants. This milk is not confined to the plants affording supplies of indiarubber, but occurs also in members of other families, as the *Papaveraceæ* (*Papaver somniferum*, or opium-poppy) and the milky *Compositæ* (*Lactuca, Cichorium, Sonchus*).

The milky sap of indiarubber-yielding plants lies chiefly in the middle layer of the bark, and is contained in a network of minute tubes ("laticiferous vessels"), which, in the *Apocynaceæ*, are found also in the inner bark or bast layer. Examinations of this sap are less complete than they might be, and have mostly been made upon samples transported from S. America in closed vessels. A specimen analysed by Faraday gave 31·70 per cent. caoutchouc, 7·13 wax and bitter principle, 2·90 matter soluble in water but insoluble in alcohol (? gum), 1·90 albumen, 56·37 water, acetic acid, and salts. The acidity was clearly due to fermentation. The fresh milks of some European uphorbias (*Euphorbia Cyparissias* and *E. platyphylla*) reveal the presence of water, resin, caoutchouc, essential oil, albumen, gum, yellowish-brown extractive matter, sugar, starch, fatty oil, tartaric acid, malic acid, &c. The chief ingredients are:—

	E. Cyparissias.	E. platyphylla.
Water	72·13	77·22
Resin	15·72	8·12
Gum	3·64	2·15
Caoutchouc	2·73	0·73

Their respective sp. grs. at ordinary temperatures are 1·0449 and 1·0468.

According to Adriani, the fresh milk of indiarubber and guttapercha plants appears under the microscope as a kind of emulsion, a clear liquid having suspended in it minute ($\frac{1}{12250}$ in. diam.) globules of caoutchouc. Raw balata exhibits the same appearance. The milk of the above-named euphorbias coagulates on exposure to the air. The same is the case with indiarubber. That the caoutchouc is held in suspension in the juice by the agency of ammonia, gains probability from the fact that many of the fresh milks have an ammoniacal odour, and that the addition of liquid ammonia is resorted to as a preventive of coagulation. Exposure of the milk to the air causes a change (usually reddening) of colour. The presence of an indiarubber in a plant may always be detected by making an incision, and testing whether the exuding milk will coagulate into an elastic fibre when rubbed between the fingers. An incision in the dry bark of such plants will disclose parallel elastic threads. The main distinctive features of all the members of this group are their elasticity, and their insolubility in water, alcohol, alkalies, and organic acids. Their composition is somewhat complex, and their market value depends upon a proportionate abundance of the elastic substance, with a relative absence of a certain oxidized, viscid, resinous body soluble in alcohol, and whose formation is in great measure prevented by rapid evaporation of the milk, and other means of avoiding oxidation.

In quantity, indiarubber and its allies are found in numerous tropical and subtropical plants of the families *Euphorbiaceæ, Apocynaceæ, Asclepiadaceæ, Sapotaceæ, Lobeliaceæ, Artocarpaceæ*, and *Moraceæ.* The following list embraces the chief plants yielding indiarubber-like products:—

Euphorbiaceæ.—Hevea [*Siphonia*] *spp.* (Pará Indiarubber); *Manihot Glaziovii* (Ceará Indiarubber); *Mabea spp.; Omphalea cordata; Sapium spp.; Euphorbia spp.*

Apocynaceæ.—Urceola elastica, Willughbeia spp. (Borneo Indiarubber); *Vahea spp.* (Mozambique or Madagascar Indiarubber); *Hancornia speciosa* (Mangabeira or Pernambuco Indiarubber); *Landolphia spp., Tabernæmontana sp.* (African Indiarubber).

Asclepiadaceæ.—Calotropis gigantea, Cryptostegia spp., Alstonia spp. (Indiarubber).

Sapotaceæ.—Isonandra [*Dichopsis*] *spp.* (Guttapercha); *Sideroxylon attenuatum; Mimusops spp.* (Balata).

Lobeliaceæ.—Siphocampylus sp.

Artocarpaceæ.—Castilloa spp. (Central American Indiarubbers); *Artocarpus integrifolia; Cecropia peltata.*

Moraceæ.—Ficus spp. (Assam and Java Indiarubber); *Urostigma spp.* (African Indiarubber).

It will have been observed that the preceding classifications necessarily exclude an artificial product such as dextrine or British gum, and the fossilized resins of which amber is the chief, as well as one or two bodies, which, though really astringent extracts, are commonly included among gums,—the kinos and mochurrus. This fact, combined with the want of uniformity in different systems of classification, and the disregard for all classification exhibited by the mercantile classes, renders it inadvisable to continue a grouped arrangement in dealing with each product in particular. The following sections will therefore be arranged in alphabetic order according to the commercial names of the most important—Amber, Ammoniacum, Arabic, Asafœtida, Balata, Balm of Gilead, Bdellium, Benzoin, Cadjii, Chagual, Cherry, Chicle, Chironji, Coco-nut, Copaiba, Copal and Animi, Dammar, Dextrine, Dhoura, Dika-mali, Dragon's-blood, Elemi, Euphorbium, Frankincense, Galbanum, Gamboge, Ging and Kunnee, Guaiacum, Gurjun, Guttapercha, Guttashea, Indiarubber, Jumrasi, Jutahy-seca, Kauri, Kino, Kos, Lac, Mahogany, Mango, Mastic, Mezquite, Mochurrus, Moringa, Myrrh, Nagdana, Olibanum, Opoponax, Orange, Peru balsam, Phormium, Piney, Pitches, Retinite, Rimu, Rosin, Sagapenum, Sandarach, Sarcocolla, Satinwood, Schraufite, Storax, Tamanu and Tacamahaca, Tars, Tendoo, Thus, Tolu balsam, Tragacanth, Turpentines, Varnishes, Wood-apple, Xanthorrhœa. To these, will be appended an alphabetic list (under botanical names) of the less important plants known to afford resinous, gummy, or balsamic exudations.

Amber (Fr., *Ambre, Succin, Carabé*; Ger., *Bernstein, Agtstein*).—Amber is a fossilized resin yielded by trees that are supposed to have grown upon the greensand beds of the Cretaceous formation, the forest originally reaching probably from Holland over the German coast, through Siberia and Kamschatka, even to N. America. The tree affording this resin, an extinct species of pine, has been provisionally named *Pinites succinifer*, but Göppert has proved that the product is not necessarily from a single species, nor even confined to the *Coniferæ* at all.

The amber supply obtained from the Baltic region of Prussia is more important than the combined contributions of all other districts. In W. Prussia, the resin is found not only in the sea and on the shore, but also in a minor degree in the hilly interior. In the latter case, however, "nests" are rare, and the yield and profit of the scattered diggings are trifling. E. Prussia, and especially the part called Samland, is the great amber-producing centre. Here, particularly at Wansen, Lassan, Groskuhren, Klienkuhren, Kraxtepellen, Kreislacken, Hubnicken, and Palmnicken, amber-mining is a settled industry. The productive stratum is a "blue earth," a loose, bluish sandstone, the lower member of the marine Tertiary formation of the locality. It has a thickness of 8–28 ft., the lowest 7–11½ ft. alone being worked. The depth is 108 ft. below the surface, and 46 ft. below sea-level. The ground is worked by shafts and levels, in the ordinary way, but with extraordinary precautions against inrushes of sea-sand and water. The ground as picked down is sent to surface, and there undergoes examination. This consists in washing it with water through a long inclined trough, whose entrance is barred by a grating of 2½–3-in. apertures, to arrest large masses, which require careful breaking by hand. Men armed with nets are stationed at 6-ft. intervals along the trough, and pick out all valuable pieces. The "tailings" or waste from the trough escapes through a 0·315-in. sieve into the sea. Recently, jigging-machines have been introduced in lieu of the troughs and net-men. Their sieves have a gauge of 0·118 in., through which the earthy matters are washed, leaving the amber on the surface. These machines (20) pass 350 cwt. of earth an hour. The average output of the mines is 15,000–25,000 tubs (of about ½ ton) a month, yielding 60–120 cwt. of large, and 22–36 cwt. of small amber, the former embracing all sizes from 100 gr. to 2½ lb. The cost of production is estimated at 4*s.*–6*s.* 6*d.* a lb. The mean yield of amber is 1 *kilo.* (2·2 lb.) for every 20 cub. ft. excavated. The average local value is placed at 1*s.* 3*d.* a lb. for small, and 7*s.* 6*d.* for large. In the three years 1876–8, the total production from about 13 acres of this ground (some 160 acres have been proved or worked) was 208¾ tons of large and 60½ tons of small amber, with a total value of 174,350*l.* The working is a monopoly of the Prussian government, who received in royalties for that period 44,664*l.*

The area of the amber-bearing stratum of E. Prussia is far from being satisfactorily determined. Moreover, there is reason to believe that other strata exist at deeper levels than the one now being worked, as considerable quantities of the resin are found among soil washed away by the sea, during heavy gales, from those portions of the coast sand-hills that lie at a lower horizon. This is known as *fliesen* amber, in contradistinction to the *erd* amber of the mines; it is softer and of less uniform colour. This marine amber is obtained by dredging at Schwarzort, on the Kurische Haff, near Memel, and by diving at Brüsterort. The yield of the former is of considerable importance, amounting to 80,000–90,000 lb. annually. The resin is found almost uniformly in separate nodules, with lignite, disseminated in the sand, at a depth of 10–12 ft. The dredged-up sand is sent ashore, and washed in the same way as the earth from the mines. The production of amber in E. Prussia in 1870 was 1415 cwt., of which, the dredging at Schwarzort contributed 740 cwt.; the diving at Brüsterort, 300 cwt.; the mines in Samland, 55 cwt.; the fishing along the coast, 320 cwt. This was much below the average, in consequence of the war. In 1874, some 360,000 lb., of all sizes and qualities, were exported.

The occurrence of amber outside the German empire is very trivial and precarious, and the products are said to be of different origin. Stray pieces occasionally found on the coasts of Norfolk, Suffolk, Essex, and Sussex, and on the Swedish and Danish shores, usually after severe storms, are doubtless washed from the Baltic beds. It sometimes occurs in the sandy deposits of the London clay at Kensington, and associated with bituminous deposits in the Paris clay; also in the French departments of Aisne, Loire, Gard, and Bas-Rhin, as well as near Basle, in Switzerland. The shores of the Adriatic and the coasts of Sicily likewise afford specimens; those from the latter often have a green or violet-blue colour. Some years since, an extensive bed of yellow amber was discovered in sinking a well near Prague, and pieces weighing 2–3 lb. were produced. Roumania possesses amber-deposits in the mountains of Sibicio, Valley of Bugeo, which, rationally exploited, might become important. The prevailing colour of the product is brown, but all shades occur, from orange-yellow or red to black, blue, and green, sometimes with specks and veins of several tints. The supply is always diminishing in quantity and in the size of the pieces. In N. Burma, amber-beds are found at an elevation of 1050 ft., to the S.-W. of the Mien Khorm plain, in the Hukong Valley. Pits are sunk to a maximum depth of 40 ft., the lower half penetrating a greyish-black carbonaceous earth. American localities where amber is met with are Cape Sable, near Magothy River, Maryland; Gay Head, near Trenton, and Camden, New Jersey; and, more recently, near Vincentown, New Jersey. All the specimens are found in the greensand formation. The sp. gr. of the Vincentown amber is less than that of water.

The principal markets for amber are Constantinople, Vienna, Moscow, Paris, London, and New York; the German towns chiefly engaged in the trade in raw and worked amber are Dantzig, Königsberg, Stolpen, Breslau, and Lübeck. The commercial varieties of the resin are divided into seven classes, based upon physical characteristics:—(1) "Shining" (*luisant*), pale-yellow or greenish; (2) "bastard" (*bâtard*), opaque, citron-yellow to dark-yellow; (3) "bone-coloured" (*couleur d'os*), dull-white, very rich in succinic acid; (4) "agate-coloured" (*couleur d'agate*); (5) "impure," containing organic remains; (6) "cloudy" (*nuageux*), unequally coloured, mainly clear-yellow; (7) "transparent," of various colours. The values vary widely with the size, form, and colour of the pieces, and the kind most esteemed in one market is neglected in another. An approximate scale of prices is as follows:—For mouth-pieces: 1 lb. in 9 pieces, 66*s.*; 1 lb. in 18 pieces, 45*s.*; 1 lb. in 40 pieces, 30*s.*; 1 lb. in 60 pieces, 19*s.* 6*d.*; 1 lb. in 100 pieces, 12*s.*; 1 lb. in 200 pieces, 9*s.*; for beads: 1 lb. in 30 pieces, 30*s.*; 1 lb. in 60 pieces, 18*s.*; 1 lb. in 100 pieces, 12*s.*

Crude amber occurs in commerce in pieces of irregular size and form; that from the mines is usually angular, with a rugose surface, while that from the sea is generally somewhat rounded by attrition, and smooth. The fracture as a rule is conchodial, and more or less lustrous. The consistence is solid, hard, and brittle. The sp. gr. commonly ranges between 1·05 and 1·095, the average being 1·065–1·070. Amber is devoid of odour and flavour at ordinary temperatures, but it affords a strong pleasant aroma when rubbed, pulverized, or burned. It is on this account employed in the perfume called *eau de luce* (see Perfumes, p. 1532). The gradations of colour have already been alluded to. Blue is due to ferric phosphate; cloudiness is caused by enclosed water in ordinary cases, but by excess of succinic acid (often in the free state) in the bone-like specimens. The cloudiness produced by entangled water can be completely removed by boiling in oil. Exposure to light darkens the colour of light-tinted amber. Amber is almost completely insoluble in water, ammonia, acetic acid, carbon bisulphide, benzol, and petroleum-spirit; slightly soluble in alcohol, ether, turpentine, chloroform, and volatile oils; and completely soluble in alkaline solutions containing camphor, and in a mixture of alcohol and turpentine-oil heated in a closed vessel. On boiling for 20 hours in linseed- or rape-oils, or heating for 40 hours in a sand-bath, it becomes transparent and ductile, allowing itself to be moulded into any form, and even enabling pieces to be cemented together. Subjected to dry distillation, it affords amber-oil (see p. 1416), succinic acid, and a solid residue. The applications of amber are chiefly as an article of ornamental turnery for the mouth-pieces of pipes and cigar-holders and for beads; for the preparation of a superior varnish (see Varnish); and for the production of amber-oil and succinic acid. As a medicinal agent it is extinct; and as a perfume, is chiefly used in the East. Our imports of it are on an increasing scale:—in 1853, 43 cwt.; in 1867, 60 cwt.; in 1870, 329 cwt. It is very extensively replaced by a false amber composed of copal, camphor, and turpentine, and costing but a mere fraction of the price of the true article. Simple tests by which the two substances can be distinguished are:—(1) Heated on a plate, the false will soon melt, while the true will bear a high temperature; (2) covered with sulphuric ether, the false is dimmed and softened, so that a penknife will pierce it; (3) on ignition, the true swells but does not run, while the false melts at once into drops; (4) amber is insoluble in cajuput-oil, while copal is quite soluble; (5) amber emits sulphuretted hydrogen when strongly heated.

Ammoniacum (Fr., *Gomme-Ammoniaque*; Ger., *Ammoniakgummi*).—The true ammoniacum of commerce is produced chiefly, if not exclusively, by *Dorema Ammoniacum.* This plant, the *ushak* of the Persians, occurs over a wide stretch of the barren country of W. Asia, particularly in the Persian provinces of Farsistan, Irak, and Khorasan. Bunge and Bienert place its north-western limit at Shahrud, S.-E. of Asterabad, whence it ranges eastwards to the deserts lying to the S. of the Sea of Aral and the Sir-Daria, while southwards it has not been met with beyond Basiran, a village of S. Khorasan (in 32° N. lat., and 59° E. long.). Dr. Grant found it abundantly in Syghan, near Bamian, on the N.-W. slope of the Hindu-Kush Mountains. One of the chief localities for the production of the gum-resin is the desert plain about Yezdikhast, between Ispahan and Shiraz.

The plant attains a height of 7 ft., and almost all portions of it, the stem, roots, leaves, and fruits are permeated by a milky juice, which escapes abundantly on the slightest puncture. Artificial tapping is not resorted to, the operation being performed by beetles, which, in the month of May, attack the plants in multitudes, and pierce them all over. The juice exudes in drops, which rapidly harden in the sun, and either remain attached to the plant, or fall to the ground. The product of this exudation, together with minor quantities which ooze out from the 3–4-year-old roots, and from the fibrous crown of the root, is collected in July–August by the peasants, and sold to dealers for transport to Ispahan or the coast. The gum-resin reaches Europe by way of the Persian Gulf and Bombay. The imports into Bombay from the Gulf were 327 cwt. in 1869–70, 520 cwt. in 1870–1, 164 cwt. in 1871–2, and 1671 cwt. in 1872–3; the re-exports from Bombay to the United Kingdom were 453 cwt. in 1871–2.

The ammoniacum of commerce is distinguished as "tear" and "lump"; the former constitutes the hardened drops in their separate form, while the latter is composed of concreted masses of these drops, more or less contaminated with gross foreign matters. The tears are dry grains of roundish form, varying in size from a millet-seed to a nut. Externally, their colour is pale cream-yellow; internally, opaque milk-white. Long keeping darkens their outer appearance to cinnamon-brown. At ordinary temperatures, the tears are hard and brittle, with a dull waxy lustre on the fractured surface, which is conchoidal. They readily soften by heat, particularly if recent. The "lumps" have a marbled or granitic appearance, and are sometimes softer, greasier, and more adhesive than the tears, sometimes harder, more brittle, and more lustrous, but always far less pure. The gum-resin has always a characteristic, non-alliaceous odour, and a bitter, acrid flavour. Its prominent constituents are resin (70 per cent.), essential oil (3–4 per cent.), gum, and water. It is used medicinally (see Drugs—Ammoniacum, Sumbul, pp. 793, 826), and in some cements.

Other Persian species of *Dorema* are capable of yielding gum-resins, though they are not known to contribute to the commercial supply. The exudation from the plant called *zah* by the Kurds, *D. Aucheri,* affords a very good article. These species, however, are far less abundant than the one producing the officinal drug. No attempt seems to have been made to cultivate any of these plants in India or Australia, though the conditions for success would appear to be present.

Moroccan or African Ammoniacum must not be confounded with the Persian product just described. It is an object of commerce with Egypt and Arabia, where it is employed, as of old, in fumigating. The plant affording it is called *fashook* in Arabic, and has been hitherto referred to *Ferula orientalis*, or *F. tingitana*; but Hooker and Ball consider it decidedly an *Elæoselinum*, probably *E. humile.* Leared was told that this plant grows at a place two days from Mogador, on the Morocco road; but Hooker and Ball were assured that it is found nowhere along that route, nor nearer to it than El Araiche, a place lying north of Morocco city, which is confirmed by information gathered by R. Drummond Hay, to the effect that it occurs near Morocco, and chiefly around Tedla. Lindley and others would extend the habitat of the plant to all N. Africa, as far as Syria, Rhodes, and Chios, and into Armenia and the E. Caucasus. But the product is obtained only in a very circumscribed district of Morocco, as stated, and is shipped occasionally at Mazagan and Mogador. It occurs in large, compact masses, of dark colour, formed by the agglutination of greenish or fawn-coloured tears. The main constituents are 67 per cent. resin and 9 per cent. gum. It is readily distinguished from the Persian officinal article by resisting the effects of hypochlorites, while the latter assumes a bright-orange hue by their action.

The approximate London market value of ammoniacum is 30–40*s.* a cwt. for drop, and 12–36*s.* for siftings and blocky.

Arabic (Fr., *Gomme Arabique*; Ger., *Acaciengummi, Arabisches Gummi*).—The term "gum Arabic" is sanctioned by long commercial use, and is therefore retained here, but it is quite misplaced, only a trifling proportion of a single variety of the product being derived from Arabia. The plants yielding the many forms of this useful gum are all species of *Acacia*, a genus of shrubs or trees widely diffused in the warmer regions of the globe. The principal acacia-gums may be best described under the separate titles by which they are known in commerce, viz.:—Picked Turkey, or White Sennar; Senegal; Suakin, Savakin, Talca, or Talha; Morocco, Mogador, or Brown Barbary; Cape; E. Indian (Babul, Siris, and Kheir); and Australian or Wattle.

1. *Picked Turkey or White Sennar.*—This is the produce of *Acacia Senegal* [*A. Verek*, *Mimosa Senegal*], a species not exceeding 20 ft. in height, which grows abundantly, constituting extensive forests, in the sandy region of W. Africa, mostly north of the Senegal river. Its negro name in this district is *verek.* In S. Nubia, Kordofan, and the Atbara country of E. Africa, where the tree is also found, it is called *hasbab.* Schweinfurth's testimony, corroborated by other authorities, is to the effect that this tree alone affords the fine white gum of the Upper Nile and Kordofan. The gum usually exudes spontaneously from the trees, without requiring any mutilation of the bark; but the natives of the Somali country, opposite Aden, are accustomed to supplement the natural outflow by scoring long wounds on the stems and branches. In Kordofan, the masses of gum aggregated upon the bark are removed by an axe, and gathered in baskets. The most highly valued kind, the *hashabi*, from Dejara province (Kordofan), is despatched from El Obeid and Bara to Dabbeh, and thence down the Nile into Egypt, or from Mandjara down the White Nile. The Samhara coast, towards Berbera, produces a good gum, part of which is shipped at Massowa; some, however, reaches Egypt by way of Jedda, in the Arabian Hejaz, whence it is called Ḥejazi or Jedda gum. The gum collected in the Somali country is of three grades, styled Felick, Zeila, and Berbera. The first is gathered chiefly by the Magartam Somalis, and those who inhabit the district around Cape Gardafui. This is esteemed the best. None of it finds its way to Aden, but a little reaches Maculla and Shehr on the Arabian coast, and the mass is bought up by Banians, and shipped direct to India. In Somali Land, when the gum of a district is gathered, it is sewn up in goat-skins, and carried on camels to the great Berbera fair, or to some of the small coast settlements, for shipment to Aden or Bombay. The plant is common in Yemen and Hadramaut, but the Arabs collect very little gum from it. The natives on the S.-E. coast, between Aden and Maculla, also collect a little, but scarcely any of this is exported.

2. *Senegal.*—This variety is produced by the same species of *Acacia* as the foregoing, and is in many respects identical with it. There are three distinct harvests per annum of this gum in the French colony of Senegal. The first, whose produce is termed *gomme du bas du fleuve*, takes place in November, during the windy season following the floods. The concreted exudations of gum are removed from the branches by means of crooked sticks. It is generally buried in the still damp soil, to remove the excessive moisture; it loses much of its weight and worth by drying, and usually accumulates a coating of sand. The second crop, *gomme du haute du fleuve*, or *gomme de Galam*, is completely dry when taken from the trees, and, being carried direct to store, is much cleaner than the first. The third contribution, *gomme friable*, or *Salabreda*, comes from Upper Senegal; it is extremely friable, owing, it is said, to the annual conflagrations in the forests, and is low-priced. During the harmattan winds, the gum exudes from the bark of the trees in tears, and solidifies in the open air, the amount of exudation depending upon the force and duration of the wind. The principal districts in which Senegal gum is produced on the one side are the country of the Brakna and Tararza Moors, the Galam country, Bondou, and Bambouk; and on the other, Oualo, Cayor, and Djolof. The three chief forests producing gum for the trade with Europe are:—That of Alfatak (Afatac), situated about 15 leagues from the river, opposite Podor, and extending to Lake Cayor, occupying a large portion of the Brakna country; (2) that of Liebar (El Ebiar), 30–40 leagues from the river, in the country of the Darmancour Moors, and containing many small trees affording red gum (? *A. nilotica*); (3) that of Sahel, in the territory of the Tararza Moors, the produce of which is carried to Gahé. This last forest consists exclusively of trees yielding white gum, and it is this product which is carried to Portendick for sale to English traders. Senegal gum is exported almost entirely to Bordeaux. Here it undergoes minute classification, the chief kinds being:—(1) *Blanche*, a fine, white gum, used in pharmacy, confectionery, distilling, and for dressing calico, linen, and lace; (2) *petite blanche*, similar, but smaller; (3) *blonde*, fine gum of pale-brown tint; (4) *petite blonde*, similar, but smaller, used for gumming envelopes and dressing ordinary cotton fabrics; (5) 2^{me} *blonde*, darker than and inferior to the last, but used for like purposes; (6 to 9) *gros grabeaux*, *moyens grabeaux*, *menus grabeaux*, and *grabeaux triés*, different qualities of the more friable gum, less clear and more cracked in the interior than the first five grades; (10, 11) *friable blanche* and *friable blonde*, better qualities of the friable kind; (12, 13) *fabrique* and *petite fabrique*, especially selected for dressing textiles; (14) *poussière*, siftings, used for ink, blacking, and paint; (15) *marrons et bois*, contains fragments of wood, averaging 27 per cent. of the whole, and is used for similar purposes; (16) *boules naturelles*, in orange-sized lumps, largely used in the silk-manufactories of Lyons. Several other minor distinctions are recognized. Senegal gum on the whole is usually yellowish or reddish, and has less of the fissures so common in Picked Turkey, therefore much firmer and less readily broken. The presence of vermicular pieces is characteristic.

3. *Suakin, Savakin, Talca, or Talha.*—This kind is afforded by the *talch*, *talha*, or *kakul* (*A. stenocarpa*) and by the *ssoffar* (*A. Seyal*). The best quality, *hashabi el Jesire*, comes from Sennar,

on the Blue Nile; an inferior grade is sent from the barren plateau of Takka, lying between the E. tributaries of the Blue Nile and the Atbara and Mareb, as well as from the highlands of the Bisharrin Arabs, between Khartum and the Red Sea. The transport of the gum is effected by way of Khartum or El Melkheir (Berber), or, much more extensively, by Suakin (Savakin), on the W. coast of the Red Sea, nearly opposite Jedda. It occurs in commerce in subglobular tears, which are always much disintegrated, by reason of its brittleness, showing a conchoidal, glassy fracture. Large tears appear opaque, on account of numerous fissures. The fragments vary from nearly colourless to brownish and reddish-brown tints. Large quantities are imported from Alexandria and Suez, and it is not infrequently sold for medicinal use.

4. *Morocco, Mogador, or Brown Barbary.*—According to Hooker and Ball, the most recent authorities on the subject, this sort of Arabic gum is produced by *Acacia gummifera* (*Mimosa gummifera, Acacia coronillæfolia, Mimosa coronillæfolia, Sassa gummifera*), a scarcely-known plant of Morocco, occurring abundantly as a thorny bush in the lower region of S. and W. Morocco, according to the testimony of the natives, who call the plant *alk tlah.* The gum does not seem to be collected in the W. portion of its range in S. Morocco, but in Demnet, whence it is carried to Mogador. Possibly it is only in the hotter and drier regions of the interior that the gum is produced in quantities to be worth gathering. At any rate, the gum is yielded only during the hot, parching months of July and August, and increases according to the hotness of the weather and the sickly appearance of the tree, being least after a wet winter and in a mild summer. Some accounts suppose the Moroccan gum arabic to be derived from the same *Acacia* which is found in Senegal; but all the inquiries made by Consul R. Drummond Hay, for Hooker and Ball, agree that this plant, the *alk awarwhal* of the Arabs, is not found in Sus, no such tree existing either north or south of the Atlas Mountains, its gum being brought from Soudan, and of inferior quality to that of *A. gummifera.* It is further stated that this latter species grows chiefly in the provinces of Blad Hamar, Rahamma, and Sus. Previous writers, including Hanbury, ascribe the Moroccan and Fezzan gum to *A. nilotica* [*arabica*], the *ssant* or *sont*, which is said to range widely over Tropical Africa, as far as Senegambia, Mozambique, and Natal, and even to Sind, Gujrat, and Central India. The gum assumes the form of worm-like tears of moderate size, and of light dusky-brown tint.

5. *Cape.*—In the Cape Colony, the *doornboom, wittedoorn*, or *karródoorn* tree (*A. horrida* [*Karroo, capensis*]), the commonest tree of the S. African deserts, spontaneously yields a very large quantity of an amber-brown gum, somewhat dull and unclean, and incompletely soluble in water.

6. *E. Indian—Babul, Siris, Kheir, &c.*—All, or nearly all, the gum called "E. Indian" in commerce is African produce shipped to Europe viâ Aden and Bombay; but several Indian species of *Acacia* afford gums of more or less value, which are utilized locally, though unknown beyond the limits of the country where they grow. The *babul* kind is ascribed to *A. arabica*, and is produced in Bengal, Coromandel, and the Deccan. The gum is exuded abundantly in March–April, and occurs usually in rather large tears or portions of tears, of a more or less dark-brown colour, rather brittle, with a shining fracture, wholly soluble in water, forming a weak, dark-coloured mucilage; it is often mixed with impurities. The *kheir* gum is obtained from *A. catechu* (see Tannin—Catechu). It is in rounded tears, varying from the size of a pea to that of a small walnut, or in broken fragments; it is mostly of bright shades of dark-amber or mahogany-brown, rather friable, the tears being cracked, and of a grain resembling coarse brown sugar. The dark tears especially have a sweet flavour. The gum is readily soluble in water, giving a thin but strong mucilage of a deep brown-sherry colour. Selected samples of this gum were sent from Chanda for valuation in 1873; the report was "ordinary arabic, value 20-25*s.* a cwt." It is stated that the Chanda gum could be placed in the Bombay market at 5¼ *rupees* (10*s.* 6*d.*) a cwt.; and that by exercising some care and attention, quantities could be procured equal to the sample reported on. The *siris* gum is derived from *A. speciosa*; it is yielded in considerable quantity, and is valuable for many ordinary purposes. The quality seems to vary, some being described as equal to good *babul*, while other is considered inferior, being only partially soluble in water, and forming a kind of stiff jelly. The latter kind is in dull irregular tears, flavourless, and of a dark-brown colour; it is used for adulterating gum arabic (the imported article), and, under the name of *lera*, in printing gold- and silver-leaf patterns on calicoes. The gum does not seem to be collected or sold on an extensive scale. Other Indian *Acacia* gums are obtained from *A. modesta*, in the dry tracts between Saharunpore and Delhi: it is in little, curled, yellow pieces, quite soluble; from *A. odoratissima*, in Coromandel, the Concans, the Nilgiris, and Assam: shining rounded tears, liable to agglutinate, of dark-brown colour, resembling *babul*, flavourless, and quite soluble; from *A. ferruginea*, in the Circars and Courtallum: dark-brown shining fragments of large tears, moist, readily agglutinated and tenacious, soft, flavourless, and dissolving in water to a coloured mucilage; from *A. leucophlœa*, in Coromandel, S. Mahratta country, Sholapore, and Delhi; and from *A. sundra*, in the mountains of Coromandel, and the Sunderbunds.

7. *Australian or Wattle.*—Several Australian species of *Acacia* furnish gums bearing more or less general resemblance to the commercial gum arabic. Principal among them is the black or

green wattle-tree (*A. decurrens* [*mollissima*, *dealbata*]); next in importance are *A. pycnantha*, and *A. homalophylla*, besides *A. harpophylla* and *A. Bidwilli.* The Australian species are of much more rapid growth than the African, and the supply of gum might be rendered abundant. It has been exported for cotton-printing, adhesive, and other applications. It occurs in large hard tears, sticks, and lumps, of pale-yellow, amber, or reddish-brown colour, and transparent; it is quite soluble in water, forming a strongly-adhesive mucilage, which is less liable to crack when dry than that of some other kinds.

The trade in gums of the arabic family has no mean importance. The annual export of Senegal gum amounts to about 3,000,000 *kilo.* (of 2·2 lb.). Of Suakin gum, some thousands of bales reached Suez in 1879. Cape Colony exported 101,241 lb. in 1872. Morocco exported 5110 cwt. of gums of various kinds (including sandarach) in 1872, a quantity much below the average. The exports of unenumerated gum from Alexandretta in 1879 were:—14 tons, value 2240*l.*, to England; 20 tons, 3200*l.*, to France; 7 tons, 1120*l.*, to Italy; 9 tons, 1440*l.*, to Austria; 18 tons, 1450*l.*, to Turkey; 22 tons, 1760*l.*, to Egypt; total, 90 tons, 11,210*l.* Bagdad, in 1878, exported 24 cwt. gum arabic, value 10*l.*, to India and Europe. The imports of gum arabic into the Bombay Presidency in 1872–3 were:—18 cwt. from Turkey, 136 from the African coast, 13,106 from the Red Sea, 927 from Aden, 165 from the Persian Gulf; total, 14,352 cwt.; the exports were:—4561 cwt. to the United Kingdom, 60 to France, 3 to Trieste, and 1 to the African coast; total, 4625 cwt. Trieste has long been a most important centre of the gum arabic trade. The imports here were 2,695,100 *kilo.* (of 2·2 lb.) in 1877, 2,726,300 in 1878, and 4,638,400 in 1879; the exports in the same years were 2,707,600, 2,796,400, and 3,080,900 *kilo.* respectively. The shipments to England alone in 1879 were 1586 tons. All the gum received at Trieste is classified into the following 32 grades:—

Name.	Mean Value per 220 lb.	Name.	Mean Value per 220 lb.
1. Arabic, white, 1*a*	299 –302*s.*	18. Arabic, crude, select, 5*g*	159½–161¼*s.*
2. Ghizira, white, 1*b*	206 –208*s.*	19. Sennary and Ghizira, crude, granular, 5*h*	79 – 82*s.*
3. Arabic, pale-yellow, 2*a*	208 –210*s.*	20. Jedda, 6*a*	126 –128*s.*
4. Ghizira, pale-yellow, 2*b*	193 –195*s.*	21. Senegal, choice, 6*b*	116¾–121*s.*
5. Arabic, yellow, 3*a*	168 –173*s.*	22. Senegal, crude, 6*c*	82 – 84*s.*
6. Ghizira, yellow, 3*b*	143 –144½*s.*	23. Arabic, crude, 7*a*	114 –117½*s.*
7. Arabic, superfine, choice, 4*a*	129½–151*s.*	24. Arabic, crude, without dust, 7*b*	131 –134½*s.*
8. Arabic, fine, 4*b*	120 –121*s.*	25. Arabic, crude, granular, 7*c*	134½–137¾*s.*
9. Ghizira, fine, 4*c*	108 –111*s.*	26. Sennary, crude, and Ghizira, 8*a*	79 – 80½*s.*
10. Arabic, medium, choice, 4*d*	114 –116*s.*	27. Sennary, crude, and Ghizira, without dust, 8*b*	79 –80½*s.*
11. Ghizira, medium, choice, 4*e*	80 – 84*s.*	28. Sennary, crude, and Ghizira, granular, and without dust, 8*c*	79 – 80½*s.*
12. Arabic, granular, 5*a*	97¼– 99*s.*	29. Saukin, crude, 9	67¼– 72¼*s.*
13. Arabic, granular, 5*b*	88 – 89*s.*	30. Senegal, genuine, crude, 10	117½–119½*s.*
14. Ghizira, granular, 5*c*	77¼– 80½*s.*	31. Damaged, 11, according to quality.	
15. Suakin Sennary, granular, 5*d*	73 – 77¼*s.*	32. Powdered, 12, according to quality.	
16. Suakin, ordinary, granular, 5*e*	50½– 54*s.*		
17. Arabic, crude, granular, 5*f*	120 –121*s.*		

The imports of gum arabic into the United Kingdom were 49,305 cwt., 133,980*l.*, in 1876; 54,014 cwt., 167,503*l.*, in 1877; 59,147 cwt., 179,118*l.*, in 1878; 88,957 cwt., 256,677*l.*, in 1879; 75,397 cwt., 216,072*l.*, in 1880. The imports for 1880 were contributed as follows:—From Egypt, 51,543 cwt., 149,021*l.*; Austrian territories, 6555 cwt., 20,519*l.*; Aden, 5017 cwt., 14,669*l.*; Australia, 4657 cwt., 8962*l.*; other countries, 7625 cwt., 22,901*l.*; total, 75,397 cwt., 216,072*l.* Our imports from Austrian territories have been:—6502 cwt. in 1876, 5720 in 1877, 4411 in 1878; 6964 in 1879; from Egypt: 31,981 cwt. in 1876, 35,924 in 1877, 42,205 in 1878, 65,024 in 1879; from Morocco: 4893 cwt. in 1876, 4869 in 1877, 1459 in 1878, 2810 in 1879, 2401 in 1880; from the Cape: 3 cwt. in 1876, 26 in 1877, 45 in 1878, 32 in 1879, 23 in 1880; from S. Australia: 373 cwt. in 1876, 748 in 1877, 1172 in 1878, 4442 in 1879, 3908 in 1880. Our re-exports of gum arabic in 1880 were: 5725 cwt., 20,923*l.*, to the United States; 4689 cwt., 12,168*l.*, to Germany; 3793 cwt., 10,361*l.*, to Holland; 2562 cwt., 7373*l.*, to Australia; 2379 cwt., 5739*l.*, to Belgium; 2316 cwt., 5355*l.*, to Russia; 1991 cwt., 5719*l.*, to France; 3253 cwt., 9046*l.*, to other countries; total, 26,708 cwt., 76,684*l.*

The approximate London market values of the various kinds of gum included under "arabic" are as follows:—E. India: pale, fine, 2*l.*–3*l.* 10*s.* a cwt.; sorts, middling to fine, 1*l.* 15*s.*–2*l.* 15*s.*; garblings and siftings, 1*l.* 5*s.*–2*l.* Turkey: picked good to fine, 6*l.* 10*s.*–10*l.*; second and inferior, 2*l.* 10*s.*–5*l.* 10*s.*; in sorts, 1*l.* 10*s.*–3*l.* 5*s.* Jedda and Talca: 1*l.* 4*s.*–2*l.* Barbary: brown, 2*l.*–3*l.* 5*s.* Australia: 1*l.* 5*s.*–2*l.* 10*s.* Senegal: 2*l.* 10*s.*–3*l.*

Asafœtida (Fr., *Asafœtida*; Ger., *Asafœtida*, *Asant*, *Stinkasant*, *Teufelsdreck*).—There are at least 3 distinct kinds of asafœtida:—(1) *Hingra* in local nomenclature, produced by *Narthex Asafœtida* [*Ferula Narthex*], and constituting the drug of European commerce; (2) *Kandahari-hing*, also obtained from *Narthex Asafœtida*, but only in minute quantity, and unknown outside of India; (3) *Hing*, afforded by *Ferula alliacea* [*Asafœtida*], and officinal in India, though scarcely known beyond it.

The relative geographical distribution of these two plants, or even the limits within which they thrive, are matters of considerable obscurity, travellers mostly alluding to them without reference to their botanical identification. Their range seems to extend from Persia and the Caspian region through Afghanistan into Tibet. According to Bellew, the *hing* plant grows wild on the sandy and gravelly plains that form the W. portion of Afghanistan. It is not under cultivation, but it is tended and watered by the Kakar Afghans wherever it is found. Indeed Wood observed that the asafœtida-growing districts around Sykan or Saigan were portioned out like corn-fields, and as carefully guarded. About the commencement of March, the leaves of the plant sprout afresh from the perennial root; and during the succeeding months of April and May, when the product is most plentiful, the whole plain country between Kandahar and Herat is occupied by the Kakars of the Bori Valley and the hills about the Bolan, who almost monopolize the collection and exportation of the gum-resin. The plant is said to grow in greatest abundance at Anardarra, in the Halmand (Helmund) district, though it is also scattered all over the W. portion of Afghanistan, and extends into the N. parts of Persia and Turkestan. Bellew saw the plant in great abundance beyond the Harut river, and on the plains of Birjand and Ghayn. It is also met with on the E. side of the Indus valley, in the Jhelam basin, and on the Upper Chenab. Col. Stewart (see Proc. R. Geog. Soc., Sept. 1881, pp. 521–2–4) speaks of asafœtida (species not stated) as being the only product of the desert country crossed by him between the spring of Chasma Shutáran and the village of Zangi Chah, both situated in Khorassan, on the S.-E. border of the Dasht-i-Kavir or Great Salt Desert. The district approximately comprises the land lying between 55° and 58° E. long., and 33° and 35° N. lat. The production here is very great. He remarks that the Persians know of no use for the drug.

The collection of the gum-resin is effected in the following manner:—About April–May, the frail, withered, and vaginated stem belonging to plants of the previous year (on roots at least 4 years old), as well as the cluster of fresh, green, sheathing leaves that may have sprouted before the withered portion has been blown away by the wind, is cut away at the junction with the top of the root. A trench about 6 in. wide and deep is cut in the earth immediately surrounding the root. In some instances, it would seem that the incising of the root follows at once; in others, a period of 40 days is allowed to elapse, during which, the soil is loosely returned to the trench, and the root is further protected from the solar heat by a coating of leaves and herbage, secured by a stone. The incising operation consists in making either several deep cuts across the upper portion of the root, or in removing very thin slices from it. In both cases, the wounded surface affords a milky exudation, which may be so sparse as to coagulate in tears upon the wound, or so plentiful as to escape into the trench around the root, and there solidify in lumps more or less contaminated with earthy and sandy particles. The yield from the first cutting is termed *shir* ("milk"), being more liquid than the subsequent product; it is much less esteemed, and is very largely (20–200 per cent.) adulterated with a soft earth, wheat-flour, or powdered gypsum, mainly perhaps to give it a portable consistence. The incisions are repeated at intervals of 3–4 days, extending to a fortnight if the flow warrants it. The exudation at this time assumes a thicker condition, and is known as *pispaz*. The wounding of the root is repeated at longer intervals during June, July, and even later, until the root is quite exhausted. After every incision, the protection of the root from the sun is very carefully attended to, otherwise the heat causes the root to wither, and stops the exudation. The quantity of the gum-resin afforded by each root varies from 1 oz. to 2 lb., much depending upon the development of the roots, whose size ranges between 1 in. and 6 in. in diameter. Bellew distinguishes two kinds of asafœtida plant, called respectively *kama-i-gawi* and *kama-i-anguza*; the former is grazed by cattle and used as a pot-herb, while only the latter affords the gum-resin.

It would seem that *hing*, the produce of *Ferula alliacea*, is obtained by taking thin slices from the crown of the root, together with the gum-resin which had collected upon them, until the root is exhausted. The slices are generally extremely thin, and form but a small proportion of the whole mass. To make the commercial article, the exhausted root is collected, cut up, and mixed with the gum-resin which has been obtained as described, by means of water. The drug reaches Bombay usually in skins weighing 100 lb. or more; occasionally also in boxes. The quality varies much, chiefly in the proportion of exhausted root. On arrival at Bombay, it frequently undergoes further adulteration with gum arabic, to effect which, the packages are broken up, the contents are moistened, and the added gum arabic is trodden well into the mass by men with naked feet upon a mat; the sophisticated drug is afterwards sewn up again in the skins to appear genuine. According to the 'Pharmacographia,' this article is called also *Abushahiri-hing*, from the fact of it its being imported from Abushir (Bunder Bushehr) and Bunder Abbas, on the Persian Gulf. The term *hira-hing* is applied to a liquid of treacly consistence often found in the centre of the packages of *Abushahiri-hing*, and which is squeezed out, and retailed at a high price. When dried, it becomes solid and translucent.

Kandahari-hing is obtained solely from the leaf-bud in the centre of the root-head of *Narthex Asafœtida*, by wounding with a sharp knife, and is generally mixed with numerous leaf-buds. It reaches Bombay in small quantities, sewn up in goat-skins, forming little oblong bales, with the hair outside. When first received, it is in moist flaky pieces and tears, from which a quantity of reddish-yellow oil separates on pressure; the gum-resin itself is of dull, reddish-yellow colour, soft and elastic, with an odour of garlic and caraway-oil. By keeping, it gradually hardens, becomes brittle, assumes a rich red-brown colour, and its odour becomes more alliaceous and like that of the commercial asafœtida. The price of this pure drug is much higher than that of the ordinary. For instance, at Kandahar 1 *man-i-tabriz* (about 3 lb.) of the former sells for 4–7 *rupees* (of 2*s.*), while the latter brings only 1½–3½. It is very much esteemed by the wealthy people of Central India, and is used by them as a condiment and in medicine. The quantity is very limited, and the article is not to be found in general commerce in Bombay.

Hingra, the asafœtida of European commerce, obtained from the root of *Narthex asafœtida*, reaches Bombay from both Persia and Afghanistan. That produced in the former country, mainly in the province of Laristan, and hence known locally as *anguze-i-Lari*, arrives at Bombay viâ Afghanistan and the Bolan Pass; it is often in a moist condition when received, containing opaque milky tears, sometimes 1–2 in. long, but soon hardens. The Afghan product, according to Dr. Dymock, goes by the Indus route, and generally arrives in a hard, dry condition, very fine samples being not uncommon. Only the very poorest classes in India will use this product, which is there officinally replaced by the much more powerful *hing*, and it is received almost exclusively for re-export to Europe.

The cultivation of all the asafœtida-yielding plants would appear to be a matter of the greatest simplicity under suitable conditions of soil and climate, and the subject is one that commends itself to the attention of planters in India, Australia, and Africa. The great centre of the trade in asafœtida is Bombay. The Indian imports of the drug from Persia range between 5000 and 7250 cwt. a year, of which, only about 1800 cwt. are re-exported. In 1872–3, Bombay Presidency imported 535,360 lb. of *hingra* from the Persian Gulf, and exported of the same kind, 348,480 lb. to foreign ports, and 48,958 lb. to other presidencies. The imports of *hing* in the same year were 345,072 lb. from the Persian Gulf, 448 lb. from Bengal Presidency, 896 lb. from Madras Presidency, and 30,688 lb. from Scinde; the exports of *hing* in the same year were 1218 lb. to foreign ports, and 147,349 lb. to other presidencies. The exports of asafœtida from the Persian Gulf ports in 1879 were valued as follows:—From Bushire, 12,000 *rupees* (of 2*s.*) to India; from Lingah, 7300 to India, and 300 to Muscat; from Bahrein, 75 to Koweit, Busrah, and Bagdad. Shanghai imported 37½ *piculs* (of 133⅓ lb.) of asafœtida from Hong Kong in 1879, of which, 10¼ *piculs* were re-shipped to Chinese ports. The consumption of the gum-resin in England is comparatively trifling, and wholly medicinal (see Drugs, p. 793); on the Continent, it is in much more extensive pharmaceutical use, and is esteemed as a condiment; while in the East, including both Hindus and Mahomedans, it is much more important as a flavouring for pulse dishes than as physic.

The approximate London market value of asafœtida is 12–70*s.* a cwt. for common to fine.

It is quite possible that other species of *Ferula* occurring throughout Central Asia might or do contribute somewhat to the supply of the gum-resin, but actual information on this point is wanting.

Balata.—The gum known as balata is a product of the bullet- or bully-tree of Central and S. America, *Mimusops Balata* [*Sapota Mülleri*, *Achras Balata*]. This tree is found very abundantly in British, French, and Dutch Guiana, British Honduras, and Brazil, flourishing best on the river-banks. As a timber-tree, it was known to the earliest colonists, and its plentifully-secreted sweet milk has been used as food by the natives since time immemorial; but it was only in 1860 that experiment was made to introduce the concreted juice as a substitute for indiarubber in European industry. The first specimens were obtained from the lowlands of the swampy Canje river, and the success attending the experiments soon created a new article of commerce for Canje Creek. The supply seems still to be derived mainly from this locality, where the trees have a diameter of 6–30 in. and a height of 20–60 ft. to the lowest branches.

There would appear to be two species or varieties of the tree, one with an oval fruit giving a more ruddy milk. In French Guiana, where the tree occurs most numerously in the upper Marinoni, it bears the several names *balata rouge* or *franc*, *balata saignant*, *balata des Galibis*, and *boromé des Arrouages*. Several other *Sapotaceæ* are said to be called *balata* in Guiana and the Antilles.

The extraction of the milk is performed in the following manner. The coarse, woody, outer bark of the tree is first stripped off; the tree is then "tapped" by making a number of incisions with a cutlass, usually in an oblique direction, and extending as high up the trunk as the man's arm will reach, generally about 7 ft. Below the wounds, a ring of clay is wrapped around the tree, and serves to catch the escaping milk, which is then collected in calabashes or other non-metallic vessels. The quantity of milk thus obtained varies from 6 to 30 oz., which, when dried, gives ¾–1 lb. of solid balata. This process is not injurious to the trees, the incisions being filled up by new bark in the course of a year or two. A second method of securing the milk is to cut down the tree, and make circular cuts 1 in. broad at about 1 ft. apart throughout the whole length, placing a receptacle beneath each. An average tree will thus afford 5½–11 lb. of dry balata, as much as 45 lb. being sometimes obtained from large trees. The gum is less coloured in this case, but the tree is destroyed.

The crude gum rapidly hardens on exposure to the air, especially in the shade; in dry weather, 2–3 days suffice to give the surface the colour and consistence of leather. The slabs are turned occasionally till the whole mass is dry, and are then packed in leaves, or moulded into blocks by means of hot water. The sp. gr. of clean, dry, solid balata is 1·042. In many of its properties, it occupies an intermediate position between indiarubber and guttapercha, possessing the elasticity of the one and ductility of the other, without the intractability of the former or the brittleness of the latter, thus becoming under certain circumstances more valuable than either for industrial purposes. Heated to 49° (120° F.), it softens and may be welded, while it does not melt below 132° (270° F.). It is quite soluble in benzol and carbon bisulphide, in the cold; and in turpentine, chloroform, and petroleum, when heated; but is only partially soluble in anhydrous alcohol and ether. It is not acted upon by caustic alkalies, nor by hydrochloric acid; but is much affected by concentrated sulphuric and nitric acids. It vulcanizes readily. It was originally introduced exclusively as a manufacturing article, for insulating telegraph wires, and such purposes; but since it has become familiar in the United States, attention has been attracted to its excellent qualities as a masticatory, and factories have been established in New York, New England, Ohio, Illinois, and Tennessee, for its preparation as a chewing material, the consumption in this way amounting to 50 tons annually. Despite the industrial value of balata, its employment is decreasing, mainly owing to the difficulty of procuring supplies, by reason of the unhealthiness of the occupation. Systematic cultivation of the tree would greatly obviate this, but has not yet been attempted. Berbice exported 20,000 lb. in 1865. (See Chicle, p. 1639.)

Balm of Gilead, Mecca Balsam, or Opobalsamum.—The *Balsamodendron gileadense* [*Opobalsamum*], a native of Arabia and Abyssinia, possesses a grateful fragrance in every part, due to the presence of an oleo-resin, which exudes when incisions are made in the bark. This product was regarded with most exaggerated esteem in biblical and classical times, and still has a boundless repute in the East, but is almost unknown in European commerce. An allied or identical balsam is afforded by an Indian species, and equally valued. This latter has a syrupy consistence, and is limpid and yellow; it thickens and hardens with age. The pure article is almost completely soluble in alcohol, but it is nearly always adulterated with turpentine, olive-oil, or wax. According to Wiesner, the little balm which reaches Europe is obtained by boiling the twigs of the plant in water, and is very much inferior to the article in Oriental use.

Other *Balsamodendron* products are described under Bdellium (below) and Myrrh (p. 1674).

Bdellium.—The myrrh-like gum-resin known as "bdellium" is of three kinds, termed respectively Indian, African, and opaque, all afforded by species of *Balsamodendron*.

1. *Indian Bdellium, Googul, or Mukul.*—This is a product of two or more species, chiefly *B. Roxburghii* [*agallocha*] of Silhet and Assam, and *B. Mukul* of Sind. The former is a very hardy plant, and readily propagated by cuttings. The bark is scarified, and the liquid exudation is placed in bottles, where it clarifies by age and exposure to the sun. This is by far the less important of the two species. *B. Mukul* is a native of Arabia, and is found on rocky ground throughout Sind, at Disa in Marwar, and in Beluchistan. Both the shrub and its gum-resin are called *googul* or *guggur* by the Hill Beluchis. The gum-resin is collected by them in the cold season, by incising the tree with a knife, and allowing the exudation to fall to the ground, by which it acquires the dirty, impure state commonly exhibited by that met with in the native shops. The yield amounts to ½–1 *seer* (of 2·2 lb.). The best is clear, pure, brilliant, viscous, adhesive, soft, yellow, bitterish, and of fragrant odour. By age, it increases in bitterness, darkens in colour, and becomes hard and dry. It is largely soluble in water. It is brought into the bazars of Hyderabad and Karachi, where it sells for 2 *rupees* (4*s.*) a *maund* (80 lb). Locally it is used medicinally, both for men and horses, but chiefly as incense for burning in the temples, and (in solution) as a strengthening ingredient for mortar. The article is sometimes sold for and considered as an inferior kind of myrrh. Portions of the birch-like bark of the tree are often found adhering to it. A third species that may be mentioned is *B. pubescens*, inhabiting Beluchistan, and the hills separating that province from Sind, probably also Afghanistan, and reaching its S. limit about Karachi. It is called *bayee* by the Hill Beluchis, but is not availed of by them. In the cold season, it exudes a small quantity of a brittle gum, almost completely soluble in water, but devoid of odour and flavour, though the young shoots and buds are remarkably fragrant when bruised. The imports of bdellium into the Bombay Presidency in 1872–3 were:—200 cwt. from the Red Sea, 7 from Aden, 70 from the Persian Gulf, and 426 from Sind; total, 703 cwt.

The *googul* of the Coromandel coast is obtained from *Boswellia glabra*, that of Khandeish from *Boswellia serrata*.

2. *African Bdellium.*—The African kind is produced by *B.* [*Heudelotia*] *africanum*, a shrub

growing in S. Arabia, Abyssinia, Mozambique, and throughout the whole of tropical Africa to Senegambia. The bulk of the gum-resin comes from Senegal, where its collection is not separately conducted, but is performed by the seekers after gum arabic, the produce being mixed with the latter gum. This does not occur through confusion of the plants yielding the two articles, but rather to increase the harvest of gum arabic. Classification takes place when the mass reaches Bordeaux. African bdellium is hard, translucent in thin layers, red by transmitted light, with a bitter flavour, and a slight aromatic odour of black pepper; its fracture is of dull, slaty hue, the margins having a powdery resinous appearance. Triturated with water, it forms an emulsion. R. H. Parker states that on standing, it gives a nearly bright mucilage, with a copious brown sediment, the mucilage indicating presence of a considerable proportion of gum allied to tragacanth. This authority gives the composition of African bdellium as—15·4 per cent. soluble in alcohol (by difference), 33·2 gum soluble in water, 37·8 gum insoluble in water, 13·6 moisture. Other analyses differ extremely. There are no statistics concerning the trade in African bdellium. It appears to be employed only in Continental pharmacy.

3. *Opaque Bdellium.*—This is attributed by Parker to *B. Playfairii*, which is stated by Hanbury to produce *hotai* gum, a whiter and more brittle substance, used by the Arabs for washing their hair. It is a very hard, ochre-yellow coloured, opaque gum-resin, with but slight odour, and a bitter flavour. The tears of this substance frequently have portions of papery bark attached to their surface. Triturated with water, it forms a very good cream-coloured emulsion. Cold absolute alcohol dissolves about 50 per cent.; a considerable portion of the residue resembles bassorine. The composition is given as—47·42 per cent. soluble in alcohol (by difference), 30·01 gum soluble in water, 11·07 gum insoluble in water, 11·50 water. It occurs among the "spurious gums" imported with myrrh.

Other *Balsamodendron* products are described under Balm of Gilead and Myrrh (pp. 1636, 1674).

Benzoin or Benjamin (Fr., *Benjoin*; Ger., *Benzoë*).—The English commercial name of this resin, "benjamin," is a vulgar corruption of "benzoin," itself derived from the corrupted form *banjawi* of the old Arabic name *lubán jáwi*, or "Java frankincense." The form "benzoin" is likewise applied to a product ($C_{14}H_{12}O_2$) of the treatment of bitter-almond-oil with alcoholic solution of potash.

The resin benzoin is obtained partly from *Styrax Benzoin*, a tree indigenous to or introduced into Sumatra, Java, Borneo, Siam, and Cochin China. There are reasons for supposing that *S. subdenticulata*, of W. Sumatra, and *S. Finlaysoniana* contribute somewhat to the several qualities of the resin, but nothing definite is known on the subject. Almost equal ignorance prevails as to the distribution of the benzoin-yielding tree or trees. Crawfurd's statement that benzoin is collected on the N. coast of Borneo, in the Brunei district, is negatived by its absence from all official returns of the trade of the island. The only two countries which can with certainty be said to afford the resin are Sumatra and Siam.

The tree yielding Sumatra benzoin, called *kaminian* by the Malays, is found in the N. and E. portions of the island, especially in the Batta country, north of the equator, but not in the Achinese territory immediately beyond. It is also met with in some abundance in the highlands of Palembang, in the south, where its product is likewise collected, though said by Marsden to be in small quantity, and of dark and inferior quality. The resin brought from the interior is mostly from wild trees, growing on the mountain spurs at 300–1000 ft. But in the coast regions, considerable care and attention are devoted to the cultivation of the tree, in regular plantations, or on the edges of the rice-fields. The trees are raised from seed, and grow rapidly. The seedlings are kept clear of other plants, and generally attain a diameter of 6–8 in. at the 7th year. The first incisions (longitudinal or oblique) are now made in the bark, whence exudes a thick, whitish, resinous juice, which soon concretes in the air, and may be scraped off. The best product, locally termed "head," is that which is obtained from the incisions of the first 3 years; it contains more of the yellowish-white tears, and is softer and more fragrant. During the next 7–9 years, the exudation becomes more reddish-yellow or brown, and is known as "belly" or 2nds. The yield averages 3 lb. annually. Finally, the exhausted tree is cut down, split in pieces, and scraped to afford the 3rd quality, or "foot," which is dark-coloured, hard, and mixed with much wood-parings and other impurities. The product is carried down to the ports in large cakes (*tampangs*) covered with matting. It there undergoes preparation for market. According to Marsden, the "head" or 1sts is divided into "Europe" and "India," the former only coming into Western commerce, while the latter, with the "belly" and "foot" (2nds and 3rds), goes to Arabia, Persia, India, and Malaysia, to be burnt as an incense in temples and as a deodorizer in dwellings. The "Europe-head" is softened for packing in cubical, wooden chests, sun-heat sufficing for the finer grades, while boiling water effects the same purpose with the coarser qualities.

Less is known regarding the origin and production of Siam benzoin. Its distinct dissimilarity from the Sumatra article would infer its derivation from another species of *Styrax*, but botanists are ignorant of the facts. The distribution of the plant is also a matter of great uncertainty. Moore states that it is found only in the N. provinces of Siam, and in Laos. A French expedition in 1866–8 reported the production of the resin in the cassia-yielding forests on the E. bank of the Mekong river, N. lat. 19°. Some of the Siam benzoin is obtained by gashing the bark all over, and leaving the exuding resin to collect and harden between the bark and the wood, the former being then stripped off; but all is not thus procured. The product is conveyed in small baskets on bullock-back to the Menam river, and thus floated down to Bangkok, where it is packed in cubical boxes exactly like the Sumatra kind. It is said to be exclusively of the "head" quality.

The benzoin received into British commerce is primarily distinguished as "Siam" and "Sumatra," each sort exhibiting variety of purity and appearance. The best of the former consists of an agglutinated mass of flattened, opaque, milk-like tears of white resin; oftener it reveals white, almond-like fragments embedded in an amber-brown translucent matrix, and the white tears are occasionally very minute, or almost altogether wanting. These latter have a stratified structure, including translucent layers. The mass is brittle, with a vanilla-like odour, but little flavour, and is readily softened by heat [fusing-point, 75° (167° F.)]. The Sumatra article has a generally greyer tint than the Siam, but when good, exhibits many opaque tears in a translucent greyish-brown body, the tears diminishing as the quality declines. The odour is less powerful and pleasant than that of the preceding. The tears melt at 85° (185° F.); the greyish-brown mass, at 95° (203° F.). Both kinds contain an admixture of fragments of wood, bark, and other foreign matters. There also appears in the London market at intervals a variety of benzoin, locally distinguished as "Penang or storax-smelling benjamin," having a highly fragrant odour, quite distinct from the ordinary kinds. The source of this is a matter of obscurity.

The chief mart for benzoin is Singapore. The imports here in 1871 were 6185 cwt. from Sumatra, and 405 cwt. from Siam; the exports in 1877 were only 1871 *piculs* (2227 cwt.). Penang, in 1871, received 4959 cwt. from Sumatra for re-export. Padang (Sumatra) exported 4302 *piculs* (5122 cwt.) in 1870, and 4064 *piculs* (4838 cwt.) in 1871. Bombay imported 4902 cwt. from the Straits Settlements in 1872–3; the exports in the same year were:—1903 cwt. to the United Kingdom, 198 to the Persian Gulf, 134 to African coast, 37 to Aden, 26 to the Red Sea, and minor quantities to Turkey, Mekran, France, &c.

The principal application of the resin is in perfumery and as an incense for church use (see Perfumes). Lesser quantities of it are used in various compositions to prevent rancidity in fats; it is also the source of benzoic acid, employed in perfumery and medicine, and is an ingredient of black sticking-plaister, and the base of Friars'-balsam. The approximate London market values of benzoin are as follows:—Siam, 2nd and 1st, 10–70*l.* a cwt.; Sumatra, 2nd and 1st, 5–15*l.*; 3rd, 2*l.*–4*l.* 15*s.*

Other products which may be mentioned here are the aromatic resins afforded by *Terminalia Benzoin* in India, and by *T. mauritiana* in Mauritius. The former is esteemed as a cosmetic, and the latter as incense, but neither appears in commerce beyond the immediate neighbourhood of the locality producing it. Probably some misapprehension underlies the statement that benzoin, obtained from *Styrax Benzoin*, has recently been sent in some quantity from the Brazilian province of Bahia.

Cadjii or Cashew (Fr., *Gomme d'acajou*; Ger., *Anacardium-gummi*).—This gum is obtained by wounding the trunk and branches of *Anacardium occidentale*, the tree affording cashew-nuts (see Nuts, p. 1352), and two kinds of oil (see Oils, p. 1379). The gum is collected in Martinique, Guadaloupe, Brazil, India, and Burma. In India, the incisions are made while the sap is rising. The gum usually occurs in elongated stalactitic pieces, or cylindrical tears, varying in colour from dirty-white to dirty-brown, the S. American being mostly topaz-yellow to brownish-red. It is sub-astringent, and highly unpalatable to insects. It consists principally of arabine and dextrine, both soluble in water, with a minor insoluble portion, probably bassorine. It forms a strong, yellowish mucilage with water. In S. America, it is largely used by book-binders; it is occasionally imported from that continent into this country, and possesses the same commercial value as the common and inferior sorts of Arabic and Senegal gums (see pp. 1630–1).

Camphor.—See Camphor, pp. 571–8.

Canada Balsam.—See Turpentine—Canadian, p. 1686.

Chagual or Maguey.—This gum is afforded by one or more S. American species of *Puya* [*Pourretia*]; *P. coarctata* of Chili, and *P. lanuginosa* of Peru, have been more particularly indicated as its sources. The exudation is said to be caused by punctures from a caterpillar (*Castnia elegans*), the gum hardening on the stem, and occurring in commerce in cylindrical pieces, whose inner surface generally exhibits fragments of parenchyma, and whose size implies a diameter of ¾-1¼ in. in the stems on which the gum has concreted. The fracture of the gum is conchoidal; its colour, topaz-yellow; its hardness, about the same as gum arabic; its tenacity, somewhat less than tragacanth; its density, when air-dry, 1·866. It is exceedingly rich in bassorine, only about 16 per cent. of it being soluble in water.

Cherry (Fr., *Gomme du pays*; Ger., *Kirschgummi*).—"Cherry-gum" is a term applied very indefinitely to the gummy exudations of cherry, plum, apricot, almond, and other trees, included in the genera *Prunus*, *Cerasus*, and *Amygdalus*. The secretion of the gum takes place in the wood of these trees, as well as in the bark. The masses of this gum are usually sub-globular or reniform, and often of considerable size. The fracture is conchoidal and strongly lustrous; the colour ranges from pale-yellow to brown, the plum-gum being generally light while the cherry-gum is darker; the gum is brittle, but less easily pulverized than the *Acacia*-gums; its flavour varies from sweet to astringent, but is always insipid. The solubility in water is not complete in any variety. The peach and almond kinds are least soluble, containing but little arabine; cherry contains about 52 per cent. arabine, and 35 cerasine. These gums are not commercial articles in England, nor in Germany of late years, but continue to have some importance in French industry, those mostly employed being from cherry and plum trees.

Chicle, Mexican Gum, or Sapota.—Much uncertainty surrounds this product. It has been known in America for some time, and extensively used as a masticatory, in the same manner as balata (see p. 1635), which it closely resembles, if, indeed, it be not identical in origin. All botanists are agreed in referring it to a Sapotaceous plant, some to *Mimusops Balata* itself. The country of its production is Mexico. The differences which it exhibits in comparison with balata may easily prove to be exclusively due to the mode of preparation for market. Analyses by Prochazka and Endemann (see Bibliography, p. 1695) gave:—75 per cent. resin, 10 arabine, 9 oxalate of lime, 5 sugar, 0·5 soluble inorganic salts; this indicates it to be a product simply of direct evaporation of the milk of the plant.

Chironji.—The common Indian tree *Buchanania latifolia*, whose fruits afford an oil (see Oils, p. 1383), yields a considerable quantity of an arabic-like gum, 5 lb. being obtainable from good specimens. It is but little availed of, though the reports of experts place it in the same category with inferior *Acacia*-gums, and consider it capable of replacing these in the dressing of textiles. It is mostly soluble in water, forming a colourless mucilage equal in strength to ordinary commercial gum arabic; but it also contains some insoluble bassorine.

The cut bark of the tree is likewise said to afford a natural varnish.

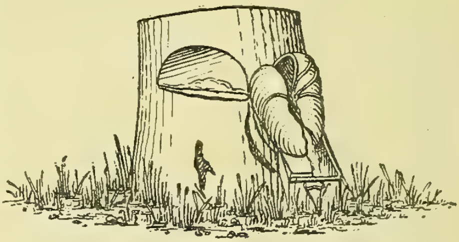
Coco-nut (Fr., *Gomme de Coco*; Ger., *Cocosgummi*).—From the bark of the coco-nut-palm, so well known for its fruit (see Nuts, pp. 1353–7) and for its oil (see Oils, pp. 1383–4), is obtained a gum termed *haari tapan* by the natives of Tahiti. It forms stalactitic masses, of red-brown to hyacinth-red colour, translucent to transparent, sp. gr. 1·45–1·57, of arabic-like hardness, and tragacanth-like tenacity, and containing 70–90 per cent. of bassorine.

Colophony.—See Rosin, p. 1680.

Copaiba, Copaiva, or Capivi (Fr., *Baume ou óleorésine de Copahu*; Ger., *Copaivabalsam*).—This balsam or oleo-resin is afforded by several forest trees belonging to the genus *Copaifera* growing in the warm portions of S. America, in Central America, and in the W. Indies. No information exists as to the relative degrees in which the various species contribute to the commercial supplies of the balsam, but the following are accredited with its production:—(1) *C. officinalis* [*Jacquini*], in the hot coast region of New Granada (Colombia) as far north as Panama, in Venezuela, and in Trinidad Island; (2) *C. guianensis* [*bijuga*], in French and Dutch Guiana, and on the Rio Negro between Manaos and Barcellos; (3) *C. coriacea* [*cordifolia*], in the dry woods (*caatingas*) of the Brazilian provinces of Bahia and Piauhy; (4) *C. Langsdorffii* [*nitida*, *Sellowii*, *Jussieui*, *glabra*, *laxa*], growing as a tree on dry *campos*, *caatingas*, and other places in the Brazilian provinces of S. Paulo, Minas Geraes, Goyaz, Mato Grosso, Bahia, and Ceara, and yielding an abundance of balsam; (5) *C. multijuga*, specially producing the Para balsam. In all these trees, resiniferous ducts, sometimes above 1 in. diam., traverse the whole stem, and occasionally become so distended with the balsam as to burst the tree asunder. Karsten attributes the origin of the balsam to a transformation of the cell-walls in the parenchyma surrounding the ducts.

The process of collecting the *copaiba blanca* or "white copaiba" of Para is described at length by Robert Cross. Formerly the tree might be seen growing in readily-accessible places, but it has now become comparatively rare, so that the collectors require to make journeys of several weeks in canoes up the Amazon tributaries, and suffer great hardship in the undertaking. The trees occur in the dense, lofty forest, on an extremely fertile soil, composed of soft white sand and vegetable mould, undulating, and watered by streams, but some 50 ft. above the level of the *gapos* or tidal floods. A successful copaiba-tree tapper must be a skilful axeman. A cavity is cut in the trunk, not much broader than the axe, but large enough to enable the workman to vary the course to the heart of the tree in such a way as not to miss the "vein" or channel, usually met with near the centre, from which the balsam flows. The floor of the cavity is neatly cut with a gentle upward slope, and should also decline to one side, so that the issuing balsam may run in a body till it reaches the outer edge. Below the cavity, a pointed piece of bark is cut and raised, which, enveloped with a leaf, serves as a spout for conveying the balsam from the tree to a tin vessel, as shown in Fig. 1170. The cavity is cut at about 2 ft. from the ground. The first 4–5 in. of the wood is white, after which it changes to a purplish-red throughout the whole interior. When abundant, the balsam flows out in a stream, full of hundreds of little, white, pearly bubbles. At times, the flow stops during several minutes, when a singular gurgling noise is made, and a fresh rush of balsam takes place. At the height of the exudation, the rate cannot be less than 1 pint a minute. The chips and the surfaces of the cavity are bedewed with drops of balsam, showing its existence throughout the wood; the bark is quite devoid of it. Though balsam escapes from the trunk even for a month after the tapping, the usual plan is not to let the receptacle remain for more than 2–3 hours. Occasionally large trees afford no balsam, the cause of which has not been ascertained. Trees in good condition will sometimes give 4 *potos* (10½ gal.) of balsam, and a collector with plenty of tin receptacles where trees are abundant may collect 5*l.* worth daily. The receptacles employed are of almost all descriptions, empty petroleum-cans being preferred.

1170.



The balsam is gathered by the Indians on the banks of the Orinoco and its upper affluents, and taken to Ciudad Bolivar (Angostura) for shipment, some of this balsam reaching Europe by way of Trinidad. It is more largely obtained on the tributaries of the Caisquiari and Rio Negro (the Siapa, Içanna, Uaupés), and the N. influents of the Amazon (the Trombetas and Nhamundá), and is sent down to Para. In S. Venezuela, the balsam is known as *aceite de palo* ("wood-oil"), the term *balsamo* being reserved for "sassafras-oil" from *Nectandra sp.* The balsam exported from Maracaibo is produced by *C. officinalis*, the *canime* of the natives. The exportation of the balsam takes place chiefly from Para, Maranham, Rio de Janeiro, Demerara, Ciudad Bolivar, Trinidad, Maracaibo, Savanilla, and Cartagena. In 1875, the shipments from Savanilla were 10,150 *kilo.*, from Para, 65,243 *kilo.*, and from Ciudad Bolivar, 99,800 lb.; the exports to New York from Ciudad Bolivar were 4165 lb. in 1878, and 1378½ lb. in 1879. Maracaibo, in 1880, exported 15,758 gal., 7474½ dol. (of 4*s.* 2*d.*). The balsam often reaches England by way of New York and Havre.

The balsams from Para, Maranham, Maracaibo, and the W. Indies are considered distinct, and are readily distinguished by experienced dealers. The first is of much less firm consistence than the second and third, and the W. Indian is opalescent, and usually deemed inferior, though probably on insufficient grounds. These differences are ascribed to variety of origin, and to oxidation and the loss of volatile constituents by exposure. The general characteristics of copaiba balsam are a more or less viscous fluid; of pale-yellow to light golden-brown colour; peculiar, aromatic, not unpleasant odour; persistent, acrid, bitter flavour; commonly transparent, sometimes opalescent; consisting of a resin held in solution by an essential oil, the latter forming 30–80 per cent.; of sp. gr. 0·940–0·993, according to the proportion of the oil; and mostly soluble in all proportions in absolute alcohol, acetone, and carbon bisulphide, in an equal volume of benzol, and in several volumes of alcohol at 0·830 sp. gr.

The balsam is very largely adulterated with castor-oil, turpentine, and other fixed and volatile oils, to which it readily lends itself by its inconstant character; it is extensively replaced by gurjun balsam here, and by the oleo-resin of *Hardwickia pinnata* in India, which are equally effective drugs. No reliable general test has yet been discovered for copaiba; but a few special tests may be mentioned. Treatment of the suspected mass with 1–4 parts petroleum-benzine will give dense floccules with 4 parts of turpentine present; and treatment with 10–12 parts of the benzine will cause a separation of even 10 per cent. of castor-oil. Most volatile oils would be detected by their ready solution in alcohol. A distinguishing test for copaiba, gurjun, and *Hardwickia* is:—Shake up 1 drop of the balsam with 19 of carbon bisulphide, add 1 drop of nitro-sulphuric acid (equal parts concentrated), and agitate: copaiba shows faint reddish-brown, with deposit of resin on the sides of the tube; gurjun, intense purplish-red, soon becoming violet; *Hardwickia*, no alteration from its pale greenish-yellow. This test will reveal 12½ per cent. of gurjun in copaiba.

The uses of copaiba are essentially medicinal (see Drugs, p. 809).

The cultivation of copaiba trees in India is advocated by Cross, who brought seeds from Brazil with that object. The site should be the best dry loam, suitable for cane or coffee; wet land is quite unfitted. The climate should be such as that enjoyed by the Para indiarubber, with which it is often naturally associated. Returns from the cultivation would be realized in about the same time as from oak plantations; a few hundred trees on an estate would much enhance its value.

See also Gurjun, p. 1651; Hardwickia, p. 1654.

Copal and Animi (Fr., *Copal, Anime*; Ger., *Kopalharz, Flussharz, Animegummi*).—The term "copal" is frequently used in a generic sense, embracing a number of resins of widely different origin. It will here be restricted to the fossil and recent copals of continental and insular Africa;

for the other kinds, readers are referred to their distinct headings—Dammar, Jutahy-seca, Kauri, and Piney.

The resin known as Bombay, E. Indian, or Zanzibar copal or animi, is a product of E. Africa, chiefly the neighbourhood of Zanzibar. It is of two kinds, fossil and recent. The exact genus and species of the tree yielding the former must remain a matter of doubt; the latter is attributed to *Trachylobium mossambicense* [*Hornemannianum*], a tree which is sometimes grouped with the very closely allied *Hymenæa spp.*, one or more of which yields a similar product in S. America (see Jutahy-seca). According to Burton, the copal-tree is called *shajar el sandarús* by the Arabs, *msandarusi* by the Wasawahili, and *mnángû* by the Wazaramo and other maritime races. It still lingers on the island and mainland of Zanzibar, and was observed by him at Monibosa, Saadani, Muhonyera, and Mzegero of Uzamaro, and was heard of at Bagarmoyo, Mbuamaji, and Kilwa. The tree is said to be abundant in the woods adjoining the inner side of the wilderness in Usambara. It grows throughout the Uzamaro (Wazamaro) country much further south, and is by no means confined to the sea-coast, but is even more abundant inland beyond the first coast-ridge. It ceases towards the interior as soon as the limestone formation makes its appearance.

The present limits of the distribution of living copaliferous trees by no means prescribe the area of the extinct forests which have been the source of the fossil copal. This is "crowed" or dug up by the coast clans and the barbarians of the maritime region. In places, it is found when sinking piles for huts; and at times, it is picked up in spots overflowed by the high tides. Burton says that the E. African seaboard, from Ras Gomani in S. lat. 3° to Ras Delgado in 10° 41′, with a medium depth of 30 miles, may be called the "copal coast," every part contributing more or less to the commercial supply. He affirms that even a section of this line, from the mouth of the Pangani River to Ngao (Monghou), would, if properly exploited, suffice for all needs. The fossil resin is a great staple of the district traversed by the newly-made road from Dar-es-Salaam, through the Wazamaro country. It exists, even in the richest diggings, only in patches, as though it had been produced by isolated trees. The natives work it nowhere systematically; they sink numerous test-holes and work those only which alight immediately upon the resin, abandoning many where diligent search would probably be remunerative. The resin usually occurs in red sandy soil; according to the Arabs, the redder the soil the better is the copal. The surface of the copal ground is generally a thin coat of white sand, covering a dark, fertile humus, the vestiges of decayed vegetation, varying from a few in. to 1½ ft. in depth. In Zanzibar Island, the subsoil is a stiff blue clay; here the copal is found in the vegetable soil overlying the clay. At Saadani, the pits are about 3 ft. deep in humus and red sandy earth; the product is not esteemed, despite the redness of the soil.

The resin is called *sandarus* by the Arabs and Hindus, *sandarusi* by the Wasawahili, and *wezi* by the Wanyam. It is distinguished as of two kinds by the Arabs and Africans. The new, recent, "tree," or "raw" copal (Fr., *Copal vert*) is called *sandarusiza miti*, or more generally *chakazi*, commonly corrupted to "jackass." This is either picked from the tree, or is found, as in Zanzibar Island, embedded at a shallow depth in the loose soil, where it has not remained long enough to undergo any change. The living trees are of large size, averaging 20–25 ft. to the first branches, and 3–5 ft. in girth. The trunk is dotted with exudations of the raw resin, and, between the bark and the wood, are frequent secretions of the resin in a liquid form. Wherever an injury has been inflicted on the tree, there an accumulation of resin will be found; when the exudation is large, it falls off and becomes covered by the dusty soil. All parts of the tree are impregnated with the resin, even extending to the fruit-pods, which contain numerous little warts or verrucosities of clear, colourless resin, covered by a thin epidermis. The *chakazi* copal is a soft mass, of smoky appearance and low value. It is sent to Bombay for the Indian and Chinese markets, where it is used for making an inferior varnish.

The true or "ripe" copal, the *sandarusi* proper, is exclusively fossil. Dr. Kirk attributes it to the same species as now afford *chakazi*. It is certainly of vegetable origin. The regular and persistent indentations and elevations of the surface, to which the term "goose-skin" has been applied, have led to the supposition that the resin escaped in a liquid or semi-liquid state, and took impressions from the sand in which it was deposited. This view is doubly erroneous. The impressions are due, not to sand, but to the structure of the cellular tissue of the tree; and their occurrence is accounted for by the fact that the secretion of the resin increases with the decay of the tree, and is much hastened by the attacks of ants and other destructive influences, thus it is chiefly formed in masses within the tree itself, and naturally takes impressions from the tissue of the surrounding wood. This occurs with the existing trees. After the complete decay and destruction of the trees, the imperishable lumps of resin have become buried in the sands which have encroached upon the fertile soil formerly occupied by the forest. The fossil resin when first dug up has no trace of the goose-skin upon it. It is hidden by the outer layer of the resin, which has undergone oxidation or some molecular change during its long burial; on removing this outer layer by an alkaline solution and sun-drying, the goose-skin becomes apparent.

The native method of collecting the fossil resin is to "crow" a hole about 6 in. diam. with a pointed stick, and scrape out the loosened earth by the hand as far as the arm will reach. Each man could easily gather 10–12 lb. daily, but the average is about 1 lb. The digging is carried on only during the *kossi*, or rainy monsoon; during the dry season, the hardness of the ground is too great for the native implements to cope with, and the resin is said to be at that time very brittle and covered with sand. The collectors do not hesitate to add much of the inferior *chakazi* to the *sandarusi* when opportunity arises. The copal gathered in Zanzibar Island is entirely *chakazi*. That of Saadani is dull-white, and considered little better than *chakazi*. That obtained on the line inland from Bagamoyo and Kaole, as far as Mubonyera, though not first-rate, is much superior to that from about Saadani. Good copal is dug in the vicinity of Mbuamaji, and the diggings are said to extend for six marches inland. The Wadenkereko, a wild tribe mixed with and stretching S. of the Wazaramo, at two days' journey from the sea, supply a mixed quality, oftener white than red; the best is procured from Hunda and the adjacent districts. The banks of the Rufiji River, especially the N. district of Wandé, supply the finest and best copal; it is dug by the Wawande tribe, who either carry it to Kikunya and other ports, or sell it to travelling hucksters. In the vicinity of Kilwa, 4 marches inland, copal is dug by the Mandandu and other tribes. The produce of Ngao (Monghou) and the Lindi creek is much cheaper than that of Kilwa, being of variable quality, mostly a dull-white *chakazi*. The island of Madagascar is said to produce both *chakazi* and *sandarusi* identical with those of the mainland; but little is known of the method of collecting, or of the precise quality. The species is called *T. verrucosum*.

At the end of the rainy season, the copal is usually carried ungarbled to Zanzibar. Hence, after being sifted and freed from foreign matters, it is sent by the Banyan retailer to the Indian market, or sold to the foreign merchant. It is usual also to effect the "cleaning" here, though this is also done at Bombay, in some European ports, and notably at Salem, in Massachusetts. It is performed in the following manner:—The resin is first washed in a dilute alkaline ley, by which it loses some 20–37 per cent. of its bulk; it is then sun-dried for some hours, and subjected to a brushing sufficiently hard to remove the outer coat, but not to injure the goose-skin. The dark "eyes" where the dirt has sunk deep are picked out by an iron tool. The next step is garbling, which is done with careful regard to colour and size, and requires great experience. As a rule, the clear and semi-transparent pieces are the best; then follow the numerous and almost imperceptible grades of dull-white, lemon-yellow, amber-yellow, rhubarb-yellow, bright-red, dull-red, blackish, and grass-green. In size, the pieces vary from that of small pebbles to 2–3 oz.; they have been known to weigh 5 and even 35 lb. Finally, the gum is put into boxes for export. The dust, of which perhaps 30 lb. daily is brushed off by each workman, is termed "sand," and cast away as of no value; it is probably genuine resin, and of some worth.

The commerce in E. African copal is extensive. Zanzibar exports some 800,000–1,200,000 lb. annually, of which, 150,000 lb. goes to Hamburg, and about 2 lacs' (say 20,000*l*.) worth to Bombay. The Bombay imports in 1872–3 were 966 cwt. from the African coast; the exports were 312 cwt. to the United Kingdom, besides 48 cwt. chiefly to the Persian Gulf, Straits Settlements, and China, and 211 cwt. to the other presidencies of India. The exports of copal in British ships from the E. coast of Madagascar in 1872 were valued at 3466*l*.

On the W. coast of Africa, which is still richer in copal than the S.-E. coast, this resin is dug over a coast length exceeding 700 geogr. miles, between lats. 8° N. and 14° S. The copal is here found in a superficial stratum of marl, sand, and clay, at a depth varying up to 10 ft. The most important copal districts of W. Africa are Sierra Leone (N. part), Accra, Benin, Gaboon, Loango, Congo, Angola, and Benguela (S. part). Of the Angola product, Monteiro says that it comes almost entirely from the Mossulo country, though it exists further north, as at Mangue Grande.

The botanical sources of W. African copal are scarcely determined with certainty. Daniell attributes the Sierra Leone article to *Guibourtia copallifera*, and perhaps some other species; but Welwitsch is unable to state positively the origin of the copal of Angola and Benguela. The W. African copal, like that of the S.-E. coast, occurs as a recent fossil. Its existence in the most recent formations, and the water-rolled form of the fragments of Sierra Leone copal found between the rivers Pongas and Malaenzi, render it probable that the trees which afforded, and perhaps still afford, copal do not belong to the coast flora, but to the interior, whence the resin has been transported by the rains and rivers. Monteiro says that, according to native accounts, the Angola copal is found below the surface of a highly ferruginous hard clay, at a depth of a few in. to 2 ft.; it probably extends much deeper, but the natives are too lazy to look for it. It is dug for during and after the last and heaviest rains, in March–May, no trees and but little grass growing above the spots where it is sought for. The resin is collected by the negroes, who at the same time gather dye-plants and gums, with the latter of which, no small quantity of copal is surreptitiously mixed. The copals of the Gaboon and Loango figure chiefly in French commerce; the large masses from Angola, Benguela, and the Congo go principally to N. America, and in minor quantities to Lisbon and other European ports. The total exports are estimated at about 2 million lb. annually.

The copals of N. and S. Guinea exhibit very distinct differences. Those of the former are divided into 2 kinds, known as "young and pebble copals of Sierra Leone." To the latter, belong the copals of Angola, Benguela, and the Congo. These three are so much alike that they are always placed together, and are known simply as "Angola." The copals of Gaboon and Loango are quite distinct again.

The "young copal of Sierra Leone" is said by Daniell to be derived from the living stems of *Guibourtia copallifera.* It consists of globular or tear-like pieces ⅓–1 in. diam., sp. gr. 1·06, of about the same hardness as S. American copal (Jutahy-seca), and of similar commercial value. It is consumed chiefly in England.

The "pebble copal of Sierra Leone" is in small pebbles ⅔–1 in. diam., colourless or white to yellowish, homogeneous, translucent to transparent, with rough exterior, and occasionally covered with an opaque crust of the thickness of paper. It is quite odourless and flavourless, is the hardest of all the W. African copals, and has a sp. gr. of 1·09.

Gaboon copal occurs in round, flattened pieces ⅓–2⅔ in. diam.; the surface is mostly smooth, but is sometimes covered with a crust of branchy striations. The grains are wine-yellow, less transparent and less homogeneous than the foregoing kind; their sp. gr. is 1·073. The fracture is conchoidal to splintery, and of glassy lustre when fresh. The scratch-line on newly fractured surfaces is smooth; on older surfaces, splintery.

Loango copal occurs in broken sticks whose natural length must amount to several spans. According to the colour, two kinds are distinguished, a white and a red. The former consists of colourless or white to yellowish grains; the latter, of reddish or brownish grains or fragments. The red copal of Loango is preferred to the white, on account of superior hardness, transparency, and homogeneity. Its sp. gr. is 1·064. The fracture is conchoidal and glistening, and the scratch-line is free from splinter. The powder does not adhere to the teeth.

Angola copal forms globular, rarely flattened pieces. The former are 1–2⅔ in. diam., while occasionally lumps as large as a child's head, and weighing 3–4 lb., are unearthed. The natural pieces are coated with an earthy, dirty-white to brown crust, which is often facetted like the surface of Zanzibar copal. But the excrescences on Angola copal are much larger than on any E. African copal, their length reaching 0·15–0·45 in. Homogeneous pieces are rare. The grains and sticks are mostly cracked, penetrated by air-bubbles, and contain fragments of bark. This copal is partly colourless, partly yellowish, reddish, or brownish. The colourless or slightly coloured are dull; the strongly coloured are bright, transparent, and homogeneous. The latter have consequently a higher price. On fresh surfaces, the scratch-line is smooth; on older, somewhat splintery. The sp. gr. lies between 1·062 and 1·081.

Hatschett states that some copal is soluble in hot alkaline leys, but Filhol says that E. Indian (which may be Zanzibar or Manilla) is not soluble even after some hours. According to Berzelius, several copals are soluble in spirit of wine on the addition of camphor. Cloëz says that copal (kind not specified) is largely soluble in chloroform, slightly in absolute alcohol. Draper names cajuput-oil as a good solvent. Copal (kind not stated) is insoluble in linseed-oil, but soluble in castor-oil, the solution mixing with spirit of wine, but, separating on standing. Violette states that Calcutta copal is soluble in linseed- and turpentine-oils, when previously heated at 350°–400° (662°–752° F.) in a closed vessel, and that the solution gives a fine varnish. Filhol remarks that the proportion of carbon diminishes in powdered copals by long keeping, and that such then become completely soluble in alcohol, ether, and turpentine-oil. (See also Varnish.)

The hardness of the copals is one of their most characteristic features, and its degree is the principal consideration in estimating their commercial value, increasing in the same proportion. All copals are scratched by calc-spar; but all, with the exception of the S. American (Jutahy-seca) scratch talc. The hardest copals are those whose hardness lies between that of crystallized copper sulphate and rock-salt, softer than the latter, harder than the former; to these, belong Zanzibar and Mozambique copals. The hardness of the copals of Sierra Leone, Gaboon, and Angola resembles that of rock-salt. Softer are those of Benguela, New Zealand (Kauri), and Manilla (Dammar), while softest of all is S. American (Jutahy-seca). The sp. gr. of the copals varies considerably, according to the amount of air inclosed in the cavities. This variation is shown in the annexed table:—

	Sp. gr. before Exhausting.	Sp. gr. after Exhausting.	Difference.
Zanzibar copal	1·067	1·068	0·001
Angola „	1·064	1·081	1·017
Brazilian „ (Jutahy-seca)	1·018	1·082	0·064
Australian „ (Kauri)	1·050	1·115	0·065
Manilla „ (Dammar)	1·062	1·121	0·059

It thus appears that the sp. gr. of a copal is in inverse proportion to its value; and that while the soft inferior copals contain much air, the hard valuable ones have less.

The London market values of the copals are approximately as follows:—Zanzibar (called "animi"): fine washed, 14–23*l.* a cwt.; good, 12–19*l.*; sorts and small, 9–16*l.*; pickings, &c., 4–12*l.* Copal: Angola, red, 3–7*l.* a cwt.; Benguela, 3*l.*–3*l.* 10*s.*; Sierra Leone, 7½–10*d.* a lb.

For the other so-called copals, see as follows:—Dammar, p. 1644; Piney, p. 1678; Jutahyseca, p. 1666; Kauri, p. 1666.

Dammar, Damar, or Dammer (Fr., *Dammar*; Ger., *Dammar*).—The name "dammar" is applied generically to a number of resins having similar properties, and distinguished by specific prefixes. They will be described here in the following order:—(1) Dammar proper, or E. Indian dammar; (2) Sal dammar; (3) Black dammar; (4) Rock dammar.

1. *E. Indian Dammar.*—This product, which is also known as "Singapore" or "white" dammar, is obtained from the gigantic Amboyna pine (*Dammara orientalis*), a native of Malacca, Borneo, Java, Sumatra, and the Moluccas, growing in the hilly country, and also cultivated to some extent in Java. The main supply of the resin is furnished by Amboyna. Immediately above the root of the tree, occur numerous excrescences, sometimes as large as a man's head, whence exudes an agglutinative liquid that solidifies after some days into elongated masses of resin. In Sumatra, the natural exudation is so abundant that no trouble is taken to make incisions in the trees. In other places, the supply is increased by making incisions on the lower portion of the trunk, and placing small receptacles for the collection of the resin. The dammar which exudes from the upper portion of the trunk forms large stalactites, at first vitreous and colourless, but gradually becoming golden-yellow, which are detached at intervals. In the dense mountain forests of Sumatra, huge pieces of dammar fall from the trees and get washed into the rivers, whence they are collected by the natives.

This kind of dammar usually occurs in commerce in nodules ⅛–¼ in. diam., occasionally of much larger size. The exterior is coated with white powder from mutual attrition, while the mass is straw-coloured or pale-amber, transparent or translucent. It splits readily, and is very friable. It is scratched by copal, and some even by mica, but is harder than rosin. It adheres only feebly by heating in the hand. It softens at about 100° (212° F.), and commences to melt at 150° (302 F.) to a clear liquid of agreeable resinous odour. The fracture is conchoidal and vitreous, and generally exhibits abundant air-bubbles and some vegetable débris. The resin splits and cracks at the temperature of the hand. The odour is balsamic when the resin is new; afterwards imperceptible. The flavour is slightly resinous; sp. gr. 1·062–1·123. It yields a small quantity of lime to water; is incompletely soluble in cold alcohol, moderately soluble in ether, soluble in boiling alcohol, fixed and volatile oils (especially turpentine- and boiling linseed-oils), chloroform, carbon bisulphide, benzol, and petroleum-spirit; but insoluble in acetic acid, nitric acid, caustic soda, and ammonia.

It is extensively used in the manufacture of varnishes for coach-builders and painters, and in mounting microscopic objects, and has long been recommended for making sticking-plaister. Inferior qualities are used in the locality of production for caulking ships and burning as incense; also for illumination, when pounded and filled into tubes of dried bamboo-stems or palm-leaves.

The exports of dammar (quoted as "gum mastic" in the Consular reports) from Manilla in 1879 were 1356 *piculs* (of 139½ lb.) to Great Britain, and 550 to the Straits and India; total, 1906 *piculs*, value, 1525*l.* And the value of the "gum" exported in 1880 was 9600*l.*

2. *Sal Dammar.*—This is produced by the *sal* tree, *Shorea* [*Vatica*] *robusta* (see Timber—Sal), in the tropical Himálaya, and along its base from Assam to the Sutlej, in the E. districts of Central India, in the W. Bengal hills, and in Borneo and Sumatra; also by this species or *S.* [*V.*] *sericea* in Malacca, and possibly by *S.* [*V.*] *Tumbuggaia* [*penicillata*] in the W. Peninsula and the forests of Cuddapa and Palghaut in Mysore. Sal dammar occurs in brittle, stalactitic pieces, pale cream-yellow, nearly opaque, each piece being striated, as if the resin had run out in thin liquid streams, and coagulated on the surface one over another. Its sp. gr. is 1·097–1·123; it is easily fusible, partially soluble in alcohol, almost completely in ether, perfectly in turpentine-oil and fixed oils, and more freely and speedily in benzol than in turpentine-spirit. These solutions are turbid. The turpentine solution (2 parts resin to 2½ parts turpentine-oil) makes a good varnish for lithographic drawings, being clear, nearly colourless, and drying rapidly without cracking; also a moderately good tracing-paper. The resin occasionally appears in the English and French markets.

3. *Black Dammar.*—The black or *kala* dammar of India is derived from one or more species of *Canarium*, the chief being *C. strictum.* This tree is common in the Alpine forests about Courtalum, in the Tinnevelly district, and is there regularly rented for the sake of its dammar. In this locality, the resin is obtained by making a great number of vertical incisions in the bark near the base of the trunk, then setting fire to the tree below the cuts, and having thus killed it, leaving it for a couple of years before collecting the exudation. The tree is killed in the hot season, and the gathering takes place in February–March. In the Coimbatore district, the dammar is extracted

from the tree by piling firewood to the height of 1 yd. around the base of the trunk, and lighting it. The resin subsequently exudes from the trunk as high as the flames reached. The operation is conducted at any season of the year, and the dammar continues to flow for 10 years between the months of April and November, and is collected in January. After yielding for 10–12 years, the tree decays. The quantity of resin obtained is stated at 30–40 *dungallies* (say 150–200 lb.). It occurs in large stalactitic pieces, of bright black colour, when viewed from a distance, but translucent and deep reddish-brown when seen in thin laminæ against the light. It is quite homogeneous, and has a vitreous fracture. It is insoluble in cold, but partially soluble in boiling alcohol on the addition of camphor. When powdered, it is readily soluble in turpentine-oil. By distillation, it yields about 78 per cent. of oil resembling rosin-oil. It is largely used in India in making bottling-wax, varnishes, &c., but in this country would hardly compete with common rosin.

Another species, *C. bengalense*, of Sylhet and the adjacent mountainous countries, yields a large quantity of pure, clear, amber-coloured resin, which soon becomes hard and brittle, and is not unlike copal, but lightly valued by the natives.

4. *Rock Dammar.*—This is furnished by two species of *Hopea*, *H. odorata* of Rangoon, Pegu, Martaban, and Tenasserim, and *H. micrantha* of Malacca, Sumatra, Borneo, and Labuan. The resin of the former occurs in nodules about the size of walnuts, of a pale-straw colour to colourless, brittle, with a shining resinoid fracture, scarcely distinguishable in appearance from the commercial E. Indian dammar (of *Dammara orientalis*). It dissolves readily in turpentine-spirit and benzol, forming a clear bright solution, drying rapidly and smoothly when applied as a varnish. In all essential qualities, it is quite equal to E. Indian dammar, and is rather superior to it in hardness. The resin of *H. micrantha* is met with in pieces having the same size as the foregoing, but darker coloured and less friable. In other respects, there is no broad difference between the two kinds.

The 1877 crop of dammar exported from Java was distributed as follows:—8272 *piculs* (of 135½ lb.) to Holland, 3674 to Singapore, 1050 to France, 736 to the Channel for orders, 615 to America, 14 to Italy; total, 14,361 *piculs*. The 1878 crop:—4161 to Holland, 2375 to France, 1721 to America, 1345 to Singapore, 410 to England, 213 to the Channel for orders; total, 10,225 *piculs*. The 1879 crop:—6820 *piculs* to France, 4413 to England, 2968 to Holland, 1957 to Singapore, 1887 to America, 814 to the Channel for orders, 343 to Italy, 262 to Port Said for orders; total, 19,464 *piculs*. The state of Sarawak, in 1879, exported 407 dollars' worth (of 4*s.* 2*d.*) to foreign countries. The approximate London market values of the dammars are as follows:—Manilla (called "copal"), 16–65*s.* a cwt.; Batavian, 70–115*s.*; Singapore, 55–105*s.*

It must be acknowledged that our information concerning the dammars of the E. Archipelago and their sources is far from being comprehensive. There are many similar products of that region of which we know practically nothing.

Dextrine, British Gum, Starch-gum, Fruit-gum (Fr., *Amidon-grillé*, *Gomme d'Alsace*, *Leiogomme*, *Gommline*; Ger., *Dextrin*, *Leiocom*, *Stärkegummi*, *Stärkemehlgummi*).—This substance, whose formula, $C_{12}H_{10}O_{10}$, is homologous with that of starch, occurs sparsely in many plants, and seems to play an important part in the development of those parts of plants in which a new formation of cells takes place. Its presence in various grains (air-dried) amounts to the following percentages:—Wheat, 4·5; wheat-bran, 5·52; barley, 6·55; rye-bran, 7·79; malt, 8·23. It is more abundant as a transformation-product of grain-starch in bread, beer, and other substances manufactured from grain; and is found also in the blood, muscle, spleen, and liver of animals, particularly graminivorous.

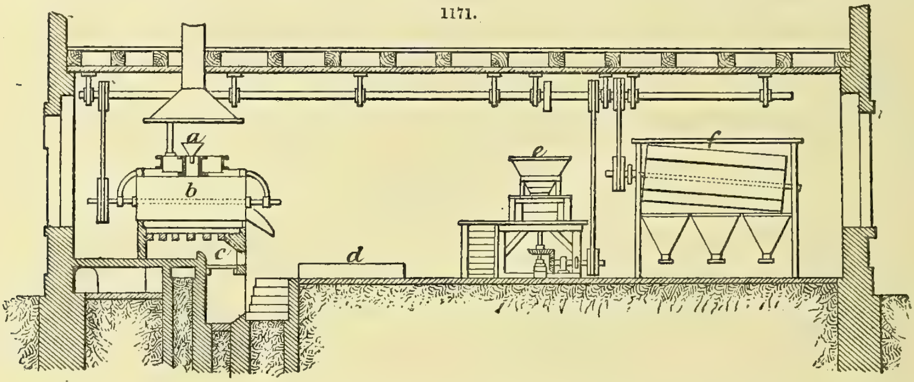
Pure dextrine is a white, amorphous, flavourless and odourless powder, sp. gr. 1·52. It is completely soluble in cold water, forming a glutinous mucilage. Commercial dextrine usually leaves a residue of 12 per cent. or more of unchanged or burnt starch. It is insoluble in absolute alcohol and in ether. Heated with dilute acids (sulphuric, hydrochloric, or acetic), it is partially transformed into grape-sugar. Alone, it is unfermentable. Heated in the presence of an inert vapour laden with moisture, it is converted into sugar, the amount of glucose thus formed increasing as the starch used is more acetous.

Commercially, the term "dextrine" is restricted to starch-dextrine prepared by the artificial transformation of starch. This may be effected in 3 ways:—(1) By the prolonged roasting of dry starch at a temperature of 200°–275° (392°–527° F.); (2) by heating starch with dilute acids for a short period; (3) by treating starch with a solution of diastase (malt-extract) at a temperature of 60°–75° (140°–167° F.). In all these cases, the formation of a certain quantity of glucose is a necessary accompaniment of the operation. In the industrial manufacture of dextrine, the dual object aimed at is the most complete transformation of the starch into dextrine, with the least possible co-production of glucose. Absolute purity is a matter of minor consideration, the technical application of the material demanding chiefly an article that will paste and thicken well. The starch employed may be of any origin, and such as is most cheaply and readily procurable on the spot (see Starch).

In manufacturing dextrine by the roasting process, it is essential that the transformation shall go on evenly and at one temperature. The limits of temperature commonly adopted are 212° and 250° (413½°–482° F.), though Payen says that a temperature of 200°–210° (392°–410° F.) produces the most perfectly soluble dextrine. Several methods are adopted for conducting the manufacture at an equable temperature, one of the best being based on the principle of an oil-bath.

This form, adopted by Proudfoot & Co., Manchester, who produce nearly 4 tons daily of dextrine, is shown in Fig. 1171. It is suited to the treatment of wheat-, rice-, and potato-starch, but only produces the article in powder form, not in transparent pieces. The starch is first dried at 80° (176° F.) in an apartment for the purpose; its subsequent loss of weight in roasting is small, 220 lb. of starch giving 176 lb. of finished dextrine of good quality. The starch is fed in through the oval hopper *a*. The double-jacketed cylinder *b* is supplied with well-refined rape-oil up to a gauge-cock. A fire is then kindled in the furnace *c*, the stirrer in the inner receptacle of the cylinder *b* is put in motion, and the starch, in charges of about 5 cwt., is introduced from the hopper *a*. The oil rapidly expands by the heat, so as to completely surround the inner cylinder of *b*. The temperature to which the oil is heated varies with the grade of dextrine required. The roasting is known to be complete when a peculiar decided odour is emitted at the hopper. The material is then withdrawn into the metallic dish *d*, about 8¼ ft. long and 4 ft. wide; the larger pieces are crushed and sifted before being pulverized in the mill *e*. It is finally placed in a sieve-drum or gauge-cylinder *f*, and is then ready for packing.

1171.



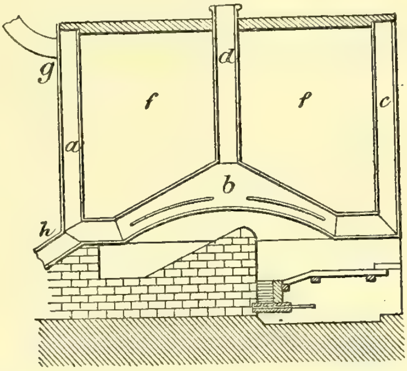
The oil can be used repeatedly, requiring only occasional replenishing as it becomes oxidized. The roasting-cylinders are best made of wrought-iron, and about 10 ft. long and 1 ft. in diameter. They are placed on a slight incline, and may be so adjusted as to work continuously, the finished product escaping at one end while the dry starch enters at the other. Several such cylinders may be placed over the same furnace, and rotated by cog-wheels. The darkest qualities of dextrine require a second roasting at a high temperature.

Payen's hot-blast furnace consists of an upper portion filled with brass trays, in which the dry starch is spread in a layer of 1–1½ in.; air, entering and circulating through passages, is heated by a furnace, and escapes into the upper chamber containing the starch; parting with its heat to the latter, it descends again to be reheated. During the first part of the operation, an exit is provided for the moisture-laden air. The great faults of this system are the impossibility of regulating the temperature, and the inequality in the roasting by reason of the starch remaining stationary.

The manufacture of dextrine by the acid process depends on the fact that anhydrous starch, moistened with a dilute scarcely-volatile acid, and heated to 100°–125° (212°–257° F.), is transformed into dextrine. Great care is necessary in arresting the process as soon as the dextrine is formed, to prevent its further conversion into sugar. The starch is mixed with a quantity (determined by experience) of dilute acid so as to form a damp powder; this is exposed to a temperature of 100°–120° (212°–248° F.) until the transformation is complete. The acids chiefly used are nitric and hydrochloric; it is essential that they contain no free chlorine, or it would pass over into the dextrine, and bleach the colours employed with the latter in printing paper, calico, &c. Sulphuric acid is seldom availed of, except for making liquid dextrine; dextrine made with it never becomes really dry, and is generally of darker colour. For the production of liquid dextrine, both oxalic and lactic acids are likewise employed, their excess after completion of the transformation being neutralized by carbonate of lime.

By Anthon's method, the pure starch is replaced by potatoes themselves, previously freed of soluble ingredients by treatment with acidulated or alkaline water, then dried, and ground fine. This material is acidulated with nitro-hydrochloric acid at the rate of 0·05–0·1 per cent. on the weight of starch. The acidulated mass is spread on linen hurdles in a drying-room at 38°–44° (100½°–111¼° F.) till it ceases to lose weight, when the temperature is raised to 70°–75° (158°–167° F.) for a time, and is finally increased to 90° (194° F.), and thus maintained for ½ hour, when the perfectly dry substance, while still hot, is placed in tin-plate moulds at 100°–125° (212°–257° F.) for 1–2 hours, by which the formation of the dextrine is completed. The final heating in the moulds is conducted in the apparatus shown in Fig. 1172. This consists of a double-jacketed kettle, whose outer receptacle *a b c* serves as a salt-water- or oil-bath, being supplied through *d*. The outer shell is encased in felt and wood; the false bottom *e* helps to facilitate the circulation of the contents of the bath. The inner receptacle is divided into a series of flat cells *f* about 1 in. diam., containing the starch to be converted. The pipe *g* serves to admit cold air or liquid into the jacket, of which the pipe *h* is the outlet.

1172.



An approved recipe for making dextrine by oxalic acid is:—500 lb. potato-starch (or an equivalent of grain-starch), 1500 lb. water, and 8 lb. oxalic acid, heated in a water-bath till the liquor ceases to give a blue colour with tincture of iodine, cooled off, neutralized with chalk, left for several days, filtered, evaporated to a doughy consistence, and slowly and completely dried.

The manufacture of dextrine by means of fermentative bodies, such as diastase, is now conducted only on a very small scale; the product always contains an appreciable quantity of sugar, and is qualified by the term *sucrée* among the French firms who make it. The process consists in heating a mixture of starch, diastase, and water at 65°–75° (149°–167° F.), and boiling the mass immediately the conversion is finished, so as to arrest as far as possible the further transformation into sugar. The syrupy nature of the article makes it difficult of transport, and it is very liable to ferment.

Mention may here be made of Pochin and Wooley's method. Thoroughly dried starch is mixed with 12½–25 per cent. of butter-milk or sour milk passed through a sieve of 40 meshes per sq. in., redried, and gently roasted till the colour is yellow to brown.

Experiments to produce dextrine from cellulose have been total failures.

Commercial dextrine is never quite pure, and rarely required to be so, but it may be rendered so by first decolorizing its aqueous solution by means of bone-black, filtering off, evaporating down, and treating with alcohol to separate the sugar; the flocculent precipitate of dextrine is filtered off, dissolved in water, and treated with alcohol, this rotation being repeated 10–12 times. The purification of dextrine made by diastase is a much more complicated matter.

Commercial dextrine varies widely in quality. It occurs most commonly as a dirty-white or pale-yellow powder, and formerly was made exclusively in this form; but latterly, it has been extensively manufactured in lumps bearing a close resemblance to Arabic and Senegal gums. Finally there is dextrine-syrup, a pale-yellow, transparent, tough, glutinous mass, used by brewers in France, but little known elsewhere. An idea of the percentage composition of dextrine intended for industrial application may be gained from the following analyses:—

	Dextrine.	Sugar.	Insoluble.	Water.
Prime dextrine ..	72·45	8·77	13·14	5·64
Dark-roasted ..	70·43	1·92	19·97	7·68
Brown dextrine ..	63·60	7·67	14·51	14·23
Gommeline ..	59·71	5·76	20·64	13·89
Older dextrine ..	49·78	1·42	30·80	18·00

Its composition is so various, and it is so often adulterated, that it should always be bought on analysis, and carefully tested.

It is very largely used in printing calicoes, glazing paper, gumming envelopes and stamps, making inks and printing-rollers, coating sticking-plaister and bandages, baking bread, and brewing beer. It is said never to become mildewed. Its approximate value is 30*s.* a cwt. in 6-cwt. casks.

Dhoura, Thoura, or Dhowra.—This gum exudes from incisions made in the bark of *Anogeissus* [*Conocarpus*] *latifolia*. The tree inhabits Islamabad, the Kennery jungles, the valleys of Concan rivers, and the inland Dekkan hills; it is very plentiful in the Melghât. A good specimen of the tree yields about 4 lb. of the gum. It is gathered carelessly, before it is sufficiently dry to come away by itself, and is much contaminated with bark, leaves, and sand. Picked samples consist of cylindrical or vermiform tears, ½ in. diam., 1½ in. long, clear, transparent, almost colourless, forming a clear, colourless mucilage with cold water, but with a small proportion of insoluble bassorine swelling up. When the latter is strained off, the mucilage is quite clear, and as tenacious as arabic. Four reports on an unpicked ordinary sample of the gum placed the probable market value at sums varying from 10 to 25*s.* a cwt. It was classed as a very low arabic; but if picked clean, and offered in quantity, it would probably soon command a better price than the maximum estimate.

Dika-mali or Cumbi, and Ouliépé.—Two species of *Gardenia*, *G. lucida* and *G. gummifera* [*arborea*], which are common in many parts of India, yield a resinous exudation; it occurs in irregular earthy-looking masses of dull olive-green colour, consisting of a mixture of the resin and its natural impurities. Its odour is peculiar and very offensive. A spirituous solution is used in dressing ulcers and to prevent mortification. Both the resin and the twigs coated with it are sold in the Indian bazars.

In New Caledonia, a yellow, aromatic resin, of disagreeable flavour and glossy fracture, is obtained from the buds of *G. Ouliépé*, *G. edulis*, and *G. sulcata.* It occurs as a powder, and in compact lumps. It closely resembles the Indian *dika-mali* or *cumbi*, and is employed by the natives as a cement and for caulking ships.

Dragon's-blood (Fr., *Sang dragon*; Ger., *Drachenblut*).—This name is applied to resins obtained from several different species of plants. The most important of the resins, and the one usually known by the name of dragon's-blood, is afforded by *Calamus Draco*, of E. Asia. Other kinds of minor significance, which will be described after the chief sort, are (2) Socotran, (3) Canary Islands', (4) W. Indian, and (5) Mexican.

1. *E. Asian.*—The distribution of *Calamus Draco*, whose stems constitute the bulk of the rattan canes of commerce, has been recorded under Cane, pp. 595–8. The abundant fruit, on arriving at maturity, is covered with an exudation of red resin, of naturally friable character. This is dislodged by gathering the fruits, and shaking or beating them in a sack or basket, when the freed resin can be sifted clean from impurities. Exposed then to the heat of the sun, or of boiling water in a closed vessel, it is softened so that it can be moulded into sticks or balls, which are immediately wrapped in a palm-leaf, generally from *Licuala spp.* This forms the best kind, or *jernang*, the "dragon's-blood in reeds" or "sticks," of commerce. The sticks have sometimes a length of 13–14 in., and a diameter of ¾–1 in., weighing about 5 oz.; smaller ones are more common. The surface of the resin appears of an intense blackish-brown; in thin pieces, it is transparent, and of a pure brilliant crimson. It has a sweetish flavour, and gives a blood-red streak on paper. The sp. gr. is about 1·2, being somewhat higher in the good qualities, and lower in the inferior. These inferior qualities are produced by boiling the pounded fruits in water, and making the resin into a mass, frequently increased by the fraudulent addition of dammar and other foreign matters. The article is known as "lump." It has a slightly acrid flavour, a weaker colour, and a much larger percentage (40 or more) of insoluble matters. Dragon's-blood melts at about 120° (248° F.), with evolution of benzoic acid. It is soluble in the alcohols, benzol, chloroform, carbon bisulphide, the oxygenated essential oils, petroleum-ether, glacial acetic acid, and caustic soda; sparingly so in ether, and still less in turpentine-oil. It is largely sent into Chinese, Indian, and European commerce from Singapore, Batavia, and Banjarmassing. It is used as a colouring agent in pharmacy, but much more extensively for making varnishes, particularly those employed by furniture-polishers.

2. *Socotran.*—The dragon's-blood of Socotra, well known in ancient medicine, is obtained from *Dracæna Ombet*, or possibly *D. schizantha*, a mushroom-like tree of 20 ft., growing only at an elevation of about 1500 ft. To obtain the resin, called *eda* by the natives, about 4 sq. in. of bark is removed, and the cavity thus formed becomes filled with the exudation in 2–3 weeks. The collection takes place in March. The product is sent from Muscat and Aden to Bombay, where it is used by the goldsmiths.

A closely similar, if not identical, article is produced by *D. schizantha*, a 25-ft. tree growing in the Somali country at 2500–5500 ft., and there called *moli.* It is said not to be exported, but either this or the foregoing kind occasionally appears in the London market in small parcels from Bombay and Zanzibar, bearing the name of "drop" dragon's-blood. It is in little tears and fragments, of clean glassy fracture, and transparent and ruby-coloured in thin sections. It is free from fruit-scales, and evolves no benzoic acid on heating.

3. *Canary Islands'.*—The dragon's-blood of the Canary Islands is obtained from *Dracæna Draco*, by making incisions in the stem. This resin is found in the sepulchral caves of the Guanches, and is supposed to have been used by them for embalming. It formed at one time a considerable article of export from the Canaries, and has not quite fallen into disuse, though it is never met with in ordinary commerce.

4. *Mexican.*—*Croton Draco*, of Mexico, yields a resin used in varnish-making, which occasionally passes by the name of dragon's-blood.

The approximate London market value of dragon's-blood is 4–5*l.* a cwt. for lump, and 10–12*l.* for fine reed.

Elemi (Fr., *Elémi*; Ger., *Elemi*).—The term "elemi" is applied to a number of resinous exudations (some confounded with animi), the chief of which is obtained from the Philippine Islands. The description of this will be followed by some account of (2) Mexican, (3) Brazilian, (4) Mauritius, (5) E. African, (6) W. African, and (7) W. Indian elemis.

1. *Philippine.*—The oleo-resin known as Manilla or E. Indian elemi has long been attributed to *Canarium commune*; this has recently been doubted by competent authorities, who are rather inclined to consider the plant a *Bursera*. It forms a tree, growing in the province of Batangas, in the island of Luzon, where it is called *abilo* by the natives, and *arbol a brea* ("pitch-tree") by the Spaniards, from the use of the resin for making torches. The resin as imported is soft, of granular consistence resembling old honey, and colourless when fresh and pure, but more usually contaminated with chips and carbonaceous matter, rendering it grey or blackish. It hardens and becomes yellow on exposure. It has a strong odour of fennel, lemon, and turpentine. It softens at 80° (176° F.), and fuses to a clear resin at 120° (248° F.). It is adopted by the British Pharmacopœia, and is imported in large quantities from Manilla. It is used principally in the manufacture of varnishes; also in felting and in medicine.

2. *Mexican.*—Mexican or Vera Cruz elemi is produced by *Amyris elemifera* [*Plumieri*], growing in Mexico and Yucatan. It is a light-yellow to whitish brittle resin, in semi-cylindrical or irregular fragments, translucent to dull and opaque. It has an agreeable odour of turpentine, and is readily masticated. It was met with in London commerce 30 years since, but is unknown now.

3. *Brazilian.*—This heading embraces the products of several species of *Icica*, as *I.* [*Protium*] *Icicariba*, *I. heterophylla*, *I. heptaphylla*, *I. guianensis*, *I. altissima*, *I. Caranna*, *I. viridiflora*, growing in Brazil, Guiana, and New Granada (Colombia). The so-called "balsams" obtained spontaneously from their trunks are highly odoriferous, and commonly used as incense in S. America. This is particularly the case with that of *I. heptaphylla*, called *hyawa* gum or *conima* resin in Guiana, and whose timber is known as "incense-wood"; and with that of *I. heterophylla*, termed "balsam of Acouchi." *I. Caranna* is named as the source of "caranna" resin, used medicinally by the Indians of Central America; but Hanbury attributes at least one kind of so-called *caranna*, *caragne*, or *caraña* gum or resin to *Bursera acuminata*. These exudations remain fluid for a considerable time, but ultimately harden. They are strangers to European commerce.

4. *Mauritius.*—Mauritius elemi is produced by *Colophonia mauritiana*, and bears a close general resemblance to the Philippine article, with which it is perhaps identical.

5. *E. African.*—See Olibanum, p. 1676.

6. *W. African.*—It is said that large cakes of elemi used to be brought to Bembe, and that it is abundant at not many days' journey; but there is possibly some confusion here with animi or copal. Nevertheless Holmes, in 1879, described an elemi from an *Icica sp.* received from Liberia under the name of copal. Externally, it seemed inferior, having a dirty blackish appearance, the white opaque porous resin only showing here and there; the odour resembled the true drug, but the article was much drier and more friable. Analysis proved it to be comparatively pure, thus—resin soluble in cold alcohol, 84·5; resin soluble in ether, 12·0; black insoluble residue, 3·5. This last is of vegetable origin, and almost exclusively fungoid or algal filaments.

7. *W. Indian.*—Wiesner describes an exudation from *Bursera gummifera* in Martinique and Guadeloupe, forming large white masses, internally greenish to yellowish.

Euphorbium (Fr., *Euphorbe*; Ger., *Euphorbium*).—This gum-resin is obtained from *Euphorbia resinifera*, a tree confined to the interior of Morocco, growing on the lower slopes of the Atlas in the S. province of Suse, and in Demenet, and notably at Netifa and Imsfuia (Mesfioua). Incisions are made by a knife in the green fleshy branches, whence exudes an abundance of milky juice, which hardens on exposure, encrusting the stems down which it flows, and is collected in September. The collectors adopt the precaution of covering mouth and nose during the operation, to exclude the small dusty particles, which provoke intense sneezing. The gum-resin once had a wide medicinal use, but the trade in it is now rapidly declining, and its consumption is restricted to veterinary practice, and as an ingredient of a marine paint. What little is exported is shipped at Mogador. Our imports in 1870 were 12 cwt.; since then there is no return. A small quantity recently sold in London at 28*s.* a cwt.

Frankincense.—The name frankincense properly belongs to olibanum, and the true drug will be described under that head (see p. 1676). The term "common frankincense" is a synonym for gum thus, a coniferous product (see Thus, p. 1684), and is also applied to another pine-resin). There remains the resinous exudation known as "W. African frankincense" for description in the present article.

The tree affording this, *Daniellia thurifera*, is a native of Sierra Leone and circumjacent regions, being especially abundant in the mountainous districts W. of Freetown, and the wooded slopes near York, Lumley, and Goderich villages. It is said also to be met with on the forest declivities of

Fernando Po, and in Yoruba, where it is called *ogea*. In Sierra Leone, both the tree and the exudation are termed *bungo*. The naturally exuded gum-resin mostly appears in a liquid state, of white or pale-straw colour; in some seasons, it oozes so copiously from the branches that the ground and shrubs beneath become thickly covered with white spots. This does not occur so profusely from the cortex, and, when so produced, appears in thin, shallow, whitish streaks, resembling a saline efflorescence when dry. The natural exudation would not appear to be gathered. But the tree is much attacked by an insect which perforates the bark in all directions, and through the apertures made by it, the gum-resin issues as a liquid mingled with and coloured by the woody débris, and accumulates in masses, which fall to the earth, harden, and are collected for sale. Further quantities are procured by stripping dead or unsound bark from the tree, the more decayed portions being commonly saturated by the exudation. Both kinds, frequently mixed, appear in the market at Freetown, and are largely consumed locally by the native women for anointing. The product seems to be unknown in European commerce.

Galbanum (Fr., *Galbanum*; Ger., *Galbanum*, *Mutterharz*).—Premising that much ignorance still surrounds the origin of this medicinal gum-resin, it seems to be at any rate chiefly derived from two species of *Ferula*. These are: (1) *F. galbaniflua*, the *khassuch* of the Persians, and *boridsheh* of the Mazanderan dialect, inhabiting the foot and slopes (4000–8000 ft.) of the Demavend mountains in N. Persia, the mountains near Kushkak and Churchura (Jajarud), and the neighbourhood of Sabsawar; and (2) *F. rubricaulis* [*erubescens*], growing in the gorges of the Kuh Dinar range in S. Persia, and locally throughout the whole of N. Persia, as on the Dalmkuh mountain, on the slopes of the Elvend near Hamadan, at intervals on the edge of the great central salt-desert of Persia, on the mountains near Sabsawar, between Ghurian and Khaf, west of Herat, and on the desert plateau west of Khaf. The gum-resin of the former species is said to be gathered by the inhabitants of the district of Demavend, though it is not any special object of industry; that of the latter species is collected for commercial purposes around Hamadan, and constitutes "Persian" galbanum.

Existing accounts of the collection of galbanum are imperfect and contradictory; possibly different systems prevail in different localities. Buhse states that the gum-resin exudes freely and spontaneously from the lower part of the stem and the bases of the leaves. Geoffroy says that it is extracted by making large incisions in the stem at about 3 in. above the root, when it escapes in drops, and at the end of a few hours has dried sufficiently to be collected. Landerer asserts that the stem is scarified, and a mussel-shell placed beneath to catch the exudation. The appearance of the bulk of the galbanum of commerce favours the supposition that it is principally drawn from incisions in the roots, few samples occurring free from an abundance of root-fragments.

Galbanum is usually classified into two kinds, "tears" and "lump." The drops or tears of Levantine commonly adhere so as to form a mass, generally compact and hard, but the Persian are occasionally soft to fluidity. Their size varies from that of a lentil to that of a hazel-nut; and their colour, from light-brown to yellowish or greenish. The odour is peculiar, aromatic, and not unpleasant; the flavour, bitter, alliaceous, and objectionable. In some samples, the tears are dull and waxy, changing from light-yellowish to orange-brown by keeping, with little disposition to concrete, and a savin-like odour. The sp. gr. of the drug is about 1·212. It consists essentially of about 50–70 per cent. of soft resin, soluble in ether and alkaline leys (even milk of lime), but not entirely in carbon bisulphide; 3–7 per cent. of volatile oil; and 18–23 per cent. of a gum resembling bassorine in its solubility.

The so-called "Levant" galbanum enters Europe viâ Trieste and Marseilles. Some is said to reach London from Bombay. Very large quantities pass into Russia by way of Astrakan, Orenburg, and Nijni-Novgorod, wrapped first in skins and then in mats, and each package weighing about 60–80 lb.

The uses of galbanum are almost wholly medicinal (see Drugs, p. 811), though it is said to be an ingredient of some cements.

The approximate London market value of galbanum is 6*d.*–1*s.* 3*d.* a lb.

Gamboge (Fr., *Gomme Gutte*; Ger., *Gutti*, *Gummigutt*).—Some account of this gum-resin has already been given under Pigments (see p. 1551). In addition to the species there indicated as affording the pigment, it would seem that a similar colouring matter is derived from *Stalagmites ovalifolius* in Ceylon, and from *Vismia guianensis*, *V. cayennensis*, *V. dealbata* (*lacrezeira* gum in Brazil), and *V. sessiliflora* in S. America, though none of these products is known in European commerce.

The value of the gum-resin for both tinctorial and medicinal purposes is directly dependent upon the proportion of the resin present. Analyses of commercial samples of "lump," "pipe," and "powder" gamboge, by Costelo, show:—

Lump	67·6 resin,	27·4 gum,	3·8 impurities.
Pipe	79·3 „	19·45 „	0·15 „
Powder	76·6 „	22·5 „	0·7 „

The resin ("gambogic acid," $C_{20}H_{23}O_4$) is of bright reddish-brown colour, translucent, very brittle, and easily rubbed into a bright-yellow powder; it is soluble in alcohol, ether, chloroform, carbon bisulphide, ammonia and potash leys, and partially in petroleum-benzine.

Ging and Kunnee.—These names are applied locally to two grades of gum produced by *Odina Wodier*, in the Coromandel mountains and Travancore. The exudation is abundant and spontaneous, and takes place from the bark of the tree, about April. The 1st quality is white, and is called *kunnee*; of it, a man can gather about 2 lb. a day. The 2nd quality is black, and consists nominally of what has fallen to the ground, but is almost invariably mixed and sold with that obtained from *Conocarpus sp.*; of this, one man can collect 10 lb. daily. A good specimen of the tree yields about 5 lb. of gum. It is used by dyers, cloth-printers, in ink, and as medicine. Samples sent into the London market for valuation were reported inferior to chironji (see p. 1639), and priced at 10–30*s.* a cwt., much fault being found with the large proportion of insoluble matters. It was stated that if imported here, it would probably be used only as an adulterant.

Specimens of gum-resin and pitchy resin attributed to the same source must be regarded with doubt. It is to be regretted that more attention has not been paid to the exudations of *Odina Wodier*. Dr. Dymock calls the gum by the names *shimptee* and *mooi*.

Guaiacum (Fr., *Gaïac*; Ger., *Guajacharz*).—This well-known medicinal resin is obtained chiefly from *Guaiacum officinale*, and in minor quantity from *G. sanctum*. Both are natives of the W. Indies, notably San Domingo and Les Gonaives (see Timber—Lignum-vitæ). A small quantity of the resin is collected as a natural exudation in tears from the stems of the trees, but a much larger proportion is extracted artificially. This is performed in several ways. The simplest consists in making incisions in the bark of the living tree. Another method is to support logs of the wood in a horizontal position, to make an incision at the centre, and then to ignite both ends of the log; as it burns, the resin escapes from the incision. A third plan is to expose logs, which have been perforated endwise, to the influence of a brisk fire. A fourth system is to boil fragments of the wood in water, whose density has been increased by the addition of salt; the resin melts out and forms a layer on the surface of the water. The resin occurs commercially sometimes in globular tears ½–1 in. diam., but generally in masses, more or less associated with débris of the wood and bark. It is brittle, with a clean glassy fracture, transparent and greenish-brown in thin pieces. The powder is grey while fresh, but soon becomes green by exposure. The odour is balsamic; the flavour is slight, but leaves an irritating sensation in the throat. The sp. gr. is about 1·12. The fusing-point is 85° (185° F.), when a benzoin-like odour is emitted. The resin is soluble in alcohol, ether, acetone, amylic alcohol, chloroform, creasote, caustic alkaline leys, and clove-oil; slightly in other volatile oils, benzol, and carbon bisulphide. The commercial article is often much contaminated by impurities through carelessness in the collection. It is also adulterated with common pine-rosin, and is itself mixed fraudulently with scammony and jalap. Its uses are wholly medicinal (see Drugs, p. 811). It is imported almost exclusively from San Domingo, whence the exports were 36,350 lb. in 1875, but only 3320 lb. in 1879, and 1830 lb. in 1880; in the two last years, the export was entirely to the United States.

The approximate London market value of guaiacum is 9*d.*–3*s.* 6*d.* a lb.

A so-called "guaiacum" from Peru, recently imported for perfumery purposes, would seem to be a distinct product.

Gurjun-balsam or Wood-oil.—This oleo-resin, whose second name must not be confounded with the fatty oil bearing the same appellation, described on pp. 1411–2, is obtained from several species of *Dipterocarpus*. The most important are *D. turbinatus* [*lævis, indicus*] of E. Bengal, Chittagong, Pegu, Singapore, and French Cochin China, and *D. trinervis* of Java and the Philippines. Other species of minor significance are:—*D. incanus* of Chittagong and Pegu; *D. alatus* of Chittagong, Burma, Tenasserim, the Andamans, Siam, and Cochin China; *D. crispalatus* of French Cochin China; *D. zeylanicus* and *D. hispidus* of Ceylon; and *D. gracilis, D. littoralis,* and *D. retusus* [*Spanoghei*] of Java.

The extraction of the oleo-resin seems to be everywhere performed in the same manner. The operation mainly consists in scooping a basin-like hole out of the trunk of the tree at a convenient height above the ground, and periodically igniting a fire within the cavity. The heat causes the balsam to flow from the ducts containing it and to collect in the basin, whence it may be dipped or siphoned into receptacles. The tapping is effected at about the end of the dry season, or during November–February. Every 3–4 weeks, the charred surface of the cavity is chipped away, and a fresh fire is made. In large healthy trees, sometimes a second cavity is cut. Trees which appear sickly in the following season are allowed a year or two's rest. Good trees give an average yield of 30–40 gal. during the season. The oleo-resin as extracted is allowed to settle, in order that the clear liquid portion may free itself from the thick sediment or *guad*.

The balsam, being derived from several different trees and various countries, does not exhibit a constancy of character. It may be generally described as a viscid fluid consisting of about 34 per cent. of resin, and 65 of essential oil, highly fluorescent, transparent, and dark reddish-brown against the light, resembling copaiba in odour, flavour, and medicinal properties, but giving no unpleasant smell to the breath. Its sp. gr. is 0·964 at 17° (62½° F.) It is quite soluble in pure benzol, cumol, chloroform, carbon bisulphide, and essential oils; partially in methylic, ethylic, and amylic alcohols, ether, acetic ether, glacial acetic acid, acetone, carbolic acid, absolute alcohol, solution of caustic potash, many samples of commercial benzine, and petroleum-ether. Tests which distinguish it from copaiba have been given on p. 1640.

Gurjun is produced in Canara (S. India) in small quantity. It is exported from Singapore, Moulmein, Akyab, and the Malay Peninsula, and is a common article of commerce in Siam. It occurs abundantly in Samar and Albay, and probably other provinces of the Philippines, where it is known as *balao* or *malapajo*; it is sold in Albay at the rate of 4 *reals* per *tinaja* of 10 *gantas* (say 4½*d.* a pint). It is now regularly to be met with at the London drug sales. Medicinally, it is employed in skin-diseases in England, and as a substitute for copaiba in India. In the Philippines, and other localities of production, it has more importance as a varnish (best after boiling to remove the essential oil), an ingredient of lithographic inks, a preservative for iron (against rust) and for timber (against termites and other insects), and generally for application to the seams and bottoms of boats and ships. As a varnish, it is reported to dry slowly and possess little body, but the case might be different if the essential oil were boiled off.

See also Copaiba, p. 1639; Hardwickia, p. 1654.

Guttapercha.—This name, as naturalized in European commerce, embraces the inspissated juices of several species of sapotaceous trees growing wild in peninsular and insular Malaysia. Their range has been defined as lying between 6° N. and S. of the equator, and between 100° and 120° E. long.; this has been more recently curtailed to 4° N. and 3° S. lat., the finer varieties being confined between 3° 50′ N. and 1° S. lat., where the air is very humid, and the temperature ranges about 19°–32° (66°–90° F.).

The Malay word *gutta* (variously spelt) signifies "gum" simply, while *percha* is the name of the tree. The *guttas* distinguished by the Malays are as follows:—(1) *Gutta-susu*, obtained from a scientifically-unknown tree, now extinct except in the interior of Perak; the product is the most esteemed of any, on account of the firmness of texture. Must not be confounded with the Bornean article of the same name, which is a kind of indiarubber. (2) *Gutta-taban*, the "guttapercha" of commerce, which will receive further attention presently. (3) *Gutta-rambong*, and (4) *Gutta-singgarip*, kinds of indiarubber, and described in that section. (5) *Gutta-puti* or *gutta-sundek*, the product of an undetermined species of *Dichopsis* [*Isonandra*], frequently met with on the Sayong and Meeru ranges (Perak). It is obtained and prepared in the same manner as *taban*, but is much whiter and more spongy, and valued at little more than ¼ the price of *taban*; of it, some 484½ *piculs* (of 133⅓ lb.) were exported from one port in 1877. (6) *Gutta-julatong*, of unknown origin, often used in Perak for mixing with *taban* and *puti*, thus rendering them very brittle. (7) *Gutta-kolian*, said to be derived from *Isonandra* [*Dichopsis*] *Motleyana*, of the Peninsula, Java, and Sumatra; the product is used only for adulterating. (8) *Gutta-burong*, the milks of various species of *Ficus*, employed as bird-lime, and described under indiarubber.

[Since the preceding remarks have been in type, Beauvisage has published a monograph on guttapercha, see Bibliography (p. 1695), which deserves the attention of all interested in the subject; it is too late to do more here than give a brief epitome of his nomenclature:—*Dichopsis* [*Isonandra*] *Gutta* is called *gutta-balam* at Pajakomlao (W. Sumatra) and the Lampongs (S. Sumatra), *gutta-tambaga* at Lobo Along (W. Sumatra), *gutta-dadu* or *-seroja* in Banka Island, *gutta-derian* in Sokadana (S.-W. Borneo) and E. Sumatra, *gutta-percha* in Malaysia generally, *gutta-taban* in the Riou Archipelago, and *ngiato-mera* or *-to-oen* in Borneo; *Isonandra dasyphylla* [*Bintang*], is the *ngiato-bintang*; *I. Motleyana* is *kotian*; *I. macrophylla* is *ngiato-puti*; *I. Benjamina* is *ngiato-wangi*; *I. xanthochyma* is *ngiato-renkan*; *I. quercifolia* is *ngiato-tinang*; *I. rostrata* is the *ngiato-pisang* of Banka; *Dichopsis Krantziana* [*I. Krantzii*] is the *thior* of Cambodia and *chay* of Annam; *Chrysophyllum rhodencurum* is *karetandjeng*; *Cocosmanthus macrophyllus* is *karetmondjeng*; *Ceratophorus* [*Azaola*] *Leerii* is *balam-tandok*, *-tjabe*, *-trong*, or *-sonte*, or *kolan*; *Ceratophorus longipetiolatus* is *benko*; *Sideroxylon attenuatum* is *balam-tima* or *karet-pantjal.* He identifies *ngiato-dokang* as a *Bassia sp.*; and further enumerates as guttapercha-yielding plants *Bassia sericea*, *Isonandra lamponga*, *I. microphylla*, and *I. acuminata.*]

Commercial guttapercha is essentially *gutta-taban*, derived from *Dichopsis* [*Isonandra*] *Gutta*, of which there are a white-flowered and a red-flowered variety in Perak, known locally as *ngiato-puti* and *ngiato-mera.* The supplies from this species are supplemented by some of those previously mentioned; according to Burbidge, the guttapercha obtained from the Lawas district of Borneo is formed of the mingled saps of at least 5 species of *Dichopsis*, the juices of a *Ficus*, and of one or two species of *Artocarpeæ* being not infrequently added as adulterants. The *Dichopsis* [*Isonandra*] *spp.* flourish best in light rich loam with a rocky subsoil. Many of the most valuable varieties are confined to the hill-slopes at a distance from the sea, each forming a distinct grove of 200–500 trees. Small plants (1–8 ft.) of *D.* [*I.*] *Gutta* are abundant on the granitic formations in Perak up to 3500 ft.

All species are difficult to propagate, except from seed, and are very slow (25–30 years) to attain maturity. For their cultivation, it is recommended to take plants not more than 1 ft. high from the jungles; it is necessary to lift them very carefully, as they have long tap-roots, which are liable to be broken or injured, thus greatly retarding the growth of the plant, or killing it outright. These facts need to be taken into consideration in view of the rapid extermination of the trees which is now taking place. Doubtless large quantities of guttapercha, as of indiarubber, are still to be derived from the little-known interiors of Malacca, Borneo, and Sumatra, if at an increased cost; but cultivation, and some system of obtaining the product short of killing the tree, will have soon to be adopted in earnest, if a supply is to be maintained.

In Perak, the guttapercha trees are most abundant on Gunong Meeru, Gunong Sayong, and Bujong; a few large trees still exist on Gunong Babo and the Thaipeng range. In Borneo and Sulu, the Kadyans and their Murut neighbours collect considerable quantities of the gum in the surrounding forests, and convey it to Labuan for sale. A writer in the 'Journal of the Indian Archipelago' some years since says:—"To the north, the gutta collectors have reached as far as Perak on the Peninsular side of the Straits of Malacca . . . and, on the Sumatran side, as far as Pane and Bila. To the south, the whole of the Johore Archipelago, and the adjoining countries on the E. coast of Sumatra, as far as Palembang (including the forests on the Kampar, Indragire, Tunkul, Rite, Jambi, and Palembang rivers) now furnish *taban*. On the E. coast of the Peninsula, the knowledge of it has not yet advanced beyond Pahang. To the eastward, it has reached some of the rivers of Borneo, such as Brunei and Sarawak on the north, Pontianak on the west, and Koti and Passir on the east. It thus appears probable that the range of the *taban* embraces the whole of Borneo." Another author states that this tree is one of the most common in Johore. It is not found in the alluvial districts; but in undulating ground, such as that occupying the centre of the Malay Peninsula between the Indan and Batu Pahat, it occurs frequently, and, in some places, abundantly.

Generally, the collection of guttapercha is carried on immediately after the rainy season; in the dry season, the flow is very tardy, while during the rains, fever prevails, and the exudation is liable to be washed away. In Perak, no particular season seems to be recognized, and Murton was unable to learn whether the yield of the trees varies with the season; but he is of opinion that in wet seasons the guttapercha must contain more water, and need more boiling for its removal. The methods adopted for extracting the guttapercha vary somewhat among the Chinese, Malays, and Dyaks. The mature trees are felled just above the buttresses, by means of axes wielded by men standing on a stage 14–16 ft. above the ground; and the branches are immediately lopped off to prevent the sap ascending to the leaves. In Perak, the felling takes place at 5–6 ft. from the earth, and the top of the tree is also cut off at the point where it becomes too small for ringing. The ringing consists in making incisions in the bark of the felled trunk. The Binna people of the Malay Peninsula cut the bark with a *golo* (small knife) or *parang* (bill-hook) at distances of 6–18 in. apart, around so much of the trunk as is accessible while lying on the ground, at the same time removing about 1 in. of the rough outer coating of the bark on each side of the wound, but without peeling off any of the inner bark. The Malays of the same region strip off a ring of the soft bark about 1 in. wide in each case. In some districts, the bark is beaten with mallets, to accelerate the flow of the sap. The latter exudes for about an hour from each incision, and is caught in palm-leaves, coco-nut shells, and other receptacles, much, however, escaping to the ground and being lost. The extreme yields may be stated at 2 *catties* and 20 *catties* (of $1\frac{1}{3}$ lb.) per tree, the average being 3–5 *catties*. The differences in yield are not readily apparent, as the trees are usually about the same age. The crude juice, if in small quantity, may be readily inspissated or concreted by rubbing between the hands. But this is rarely done, the rule being to boil the article in water in a *kwali* or iron pan about 15 in. diam. and 6 in. deep, with the addition of various adulterants. The boiling is done partly for the purpose of driving off the water which usually gets mixed more or less with the juice, and gives a stringy and deteriorated appearance to the guttapercha. Among adulterants other than the juices of allied plants, one of the most important is coco-nut-oil, to improve the appearance; lime-juice (1 pint to 3 gal.) has the property of coagulating the guttapercha immediately on ebullition. Generally in Borneo some 20 per cent. of scraped bark is added; indeed, it is said that the Chinese traders, who buy up the gutta from the gatherers, would refuse the pure article in preference for that containing bark, to which the red colour is mainly due. On reaching the export warehouses, the various kinds are assorted and sophisticated ready for commerce. The article is exported either in the form of balls weighing 13–20 *catties* (of $1\frac{1}{3}$ lb.), or in large blocks, usually the latter for foreign ports.

The trade in guttapercha is of considerable and growing importance. Our imports of the raw article in 1880 were:—From the Straits Settlements, 62,862 cwt., value 505,821*l.*; other countries, 2994 cwt., 22,051*l.*; total, 65,856 cwt., 527,872*l.*, being an advance on previous years. Our imports from the Straits Settlements have increased from 19,665 cwt. in 1876, to 21,887 in 1877, 31,036 in 1878, and 49,387 in 1879. From Borneo direct, we received 22 cwt., value 350*l.*, in 1876, but none is recorded since. The exports of guttapercha and indiarubber combined from Borneo to Singapore in 1879 were valued at 437,027 dollars, or 91,047*l.* The proportion from each Bornean port was:—Brunei, 27,720 dol.; Labuan (received from the coast), 47,513 dol.; Sarawak, 361,794 dol. Of the figure for Sarawak, guttapercha represents 320,507 dol., leaving only 41,287 dol. for indiarubber. The little port of Sandakan shipped 6277 dol. worth of guttapercha. The exports of guttapercha from Java for the year 1877–8 were 1113 *piculs* (of 135½ lb.) to Holland, and 6 to Singapore; in 1878–9, 332 to Holland, 116 to Singapore, and 34 to England; crop of 1879, 555 to Holland, and 274 to Singapore. It has been estimated that the shipments of guttapercha from Sarawak alone during the years 1854–75 have totalled over 90,000 *piculs* (of 133⅓ lb.), representing the destruction of at least 3 million trees. Our re-exports of guttapercha in 1880 were:—4524 cwt., 53,949*l.*, to Germany; 1796 cwt., 16,100*l.*, to Holland; 1137 cwt., 13,541*l.*, to the United States; 1072 cwt., 4604*l.*, to other countries; total, 8529 cwt., 88,194*l.*

The physical and chemical properties of guttapercha, and its industrial applications, have been described in a section of the article on Indiarubber Manufactures, pp. 1162–4. It may be added that while exposed to the air and alternations of temperature, it oxidizes and decays rapidly, lasting only about 10 years on telegraph wires suspended in tunnels, but about 20 years when enclosed in iron pipes; yet in the sea, 20 years' exposure produces no visible deterioration.

The approximate London market value of guttapercha is 6*d.*–3*s.* 6*d.* a lb. for genuine, and 3*d.*–2*s.* a lb. for re-boiled.

Guttashea.—This name has been conferred upon a substance, somewhat resembling guttapercha, found in appreciable proportion (½ per cent.) in shea-butter (see Oils and Fatty Substances, p. 1410). Beyond what is there stated concerning it, Dr. Letts, who experimented upon the substance for Thomas Bros., Bristol, obligingly writes as follows:—"I did not succeed in isolating from the gum any very definite product. To the best of my recollection, the portion soluble in ether separated gradually as an almost colourless solid, but I could not determine whether or no it was crystalline. I remember that I could get no definite salts or other compounds from either it or the insoluble residue. The only other fact I considered of importance was the odour which the gum evolved on dry distillation, which was exactly like that of indiarubber (when heated). This led me to think that the gum might be allied to caoutchouc." It has been separated in a manner to admit of its industrial utilization, but no application has yet been found for it.

Hardwickia balsam.—An important oleo-resin is obtained from *Hardwickia pinnata*, a large tree, very common in the dense moist forests of the S. Travancore ghats, and found also in S. Canara. The method adopted by the natives for extracting the balsam is parallel with that current in Brazil for procuring copaiba (see pp. 1639–40). The product is a thick, viscid fluid, bearing the closest likeness to copaiba, from which it may, however, be distinguished by the tests given on p. 1640. It is used medicinally in India as a most efficient substitute for copaiba.

See also Gurjun, p. 1651.

Hog.—The term "hog-gum" (which must not be confounded with the inferior tragacanth bearing the same name, see p. 1686) is applied in Jamaica to a yellow resin resembling Burgundy pitch in appearance, which escapes as a pellucid juice from incisions in the trunk of *Moronobea coccinea.* It is used for making pitch plaisters and as a substitute for copaiba in Jamaica. In Brazil and Guiana, where it is known as *mani* or *oanani*, it is converted into torches, and employed in pitching boats.

Indiarubber (Fr., *Caoutchouc*; Ger., *Kautschuk*).—The term "indiarubber," often and conveniently shortened to "rubber," is applied to a large class of inspissated plant-juices, chiefly yielded by the species named on pp. 1627–8. In England, the name "caoutchouc" is restricted to the hydrocarbon which constitutes the main ingredient of commercial rubbers. The plan on which the present article is framed is to commence with a description of the origin and production of the commercial rubbers in their alphabetic order—African (including Mozambique, Madagascar, Liberian, &c.); Assam, Java, Penang, and Rangoon; Central American (including Cartagena, Guatemala, Guayaquil, Honduras, Mexican, Nicaragua, and W. Indies); Para; Pernambuco or Mangabeira—following with other kinds which as yet have no industrial importance, and concluding with statistics of production, export, price, &c. The industrial applications of the rubbers have already been described in the article on Indiarubber Manufactures, pp. 1142–64.

African.—Much ignorance still prevails concerning the sources and collection of the African rubbers. The Mozambique and Madagascar kinds are obtained from the climbing shrubs *voà-héré* or *voa-canja* (*Vahea madagascariensis*), *voà-hiné* (*V. comorensis*), and *V. gummifera.* The product of one of these species is said to be much superior to the others, but all are mixed indiscriminately by the natives. The preparation consists in treatment either with salt water or artificial heat. The Mozambique article occurs in orange-like balls; in "sausages," formed of slender strings of rubber wound upon a stick, which is finally withdrawn; and occasionally in smooth pieces of various size, termed "cake" or "line." The Madagascar sort consists of shapeless lumps, the better quality having a pink colour, and the lower a black.

Some rubber is produced in Mauritius by *Cryptostegia grandiflora*, and some by *Willughbeia edulis*, the latter found also in Madagascar, Chittagong, and Silhet.

A belt of rubber-yielding plants of different species extends across Tropical Africa from ocean to ocean. Within 20 miles of the coast from Liawa and the Lindi estuary (Masasi and Rovuma, E. Africa, 11° S., 38° E.), the forest becomes almost entirely formed of indiarubber vines, affording an abundant supply of fine rubber, at present gathered only in a very desultory manner by the natives, who gash the plants, and collect the exuding juice, which issues in a liquid form, and dries hard after short exposure to the air. Rolled into orange-like balls, it is taken to Lindi, where it is purchased by the Banyan merchants at about a quarter its value. Dr. Kirk has determined the plant which yields the best E. African rubber, and has obtained seeds of the species for introduction into India. It occurs in great abundance along the newly-made road from Dar-es-Salaam, in a W.-S.-W. direction, for about 100 miles towards the interior of E. Africa, through the Wazamaro country; it is apparently but little affected, except in the immediate neighbourhood of the villages, by the reckless mode of tapping employed. In many parts, a native can still collect 3 lb. of rubber daily. There are five species, but only one is considered worth tapping. Specimens received from him at Kew have been named *Landolphia florida* and *L. Kirkii*, the latter of which yields the best rubber. The *Landolphia* vine is known from Pangani inland all the way to Handei (in Usambara, E. Africa); at Magila, the rubber is made into balls for export. Dr. Kirk states that *L. owariensis* is common along the maritime region of E. Africa, and abundant at the mouth of the Zambesi, being found largely at Shupanga on that river at 100 miles from the coast. The produce of this has been shipped from Quillimane for America. The natives of the Marutse-Mabunda empire, on the Upper Zambesi, trade in rubber with the tribes to the west. The district called Mungao, extending from S. lat. 9° 25′ to Delgado in 10° 41′, yielded 90,000*l.* worth of rubber in 1877, when the industry had been only 3 years in existence. In 1878, Kilwa and Mombasa added largely to the supply. On the Victoria Lake, are one or two kinds of tree producing rubber of good quality. Rubber plants grow on the slopes of the Cameroons mountains (W. Africa), but the people do not yet know their value. Rubber trees abound on the river Djour, in the province of Bahr el Ghazal.

The *Landolphia spp.* are principal among the rubber plants of W. Africa. The rubber is collected from *L. owariensis*, extending from 10° N. to 10° S. on the coast of W. Africa, and most abundant in the highland districts of Angola; *L. florida*, frequent in inner Angola up to 1500–2500 ft., and in Liberia; and *L. Heudelotii* in Senegal. According to Speke and Grant, the natives say that the best rubber is produced by *L. florida.* The plants of this genus are woody climbers, growing well in damp rocky ravines scarcely available for other culture. Being climbers, they could not be grown in separate plantations, but would probably flourish in any tropical jungle, where trees already existed for them to ascend. Every part of the stem exudes a milky juice when cut or wounded, but this will not run into a vessel placed to catch it, as it dries so quickly as to form a ridge on the wound, which stops its further flow. The blacks collect it by making long cuts in the bark with a knife, and as the milky juice gushes out, it is wiped off continually with the fingers, and smeared on their arms, shoulders, and breast, till a thick covering is formed. This is peeled off their bodies, and cut into small squares, which are then said to be boiled in water. According to other accounts, the natives cut off a piece of the bark, and the milky juice is allowed to run into holes in the ground, or upon leaves. In some districts, they simply let the juice trickle down their arms, going from tree to tree till sufficient has accumulated, then peeling it off from the elbow in the form of a tube. Elsewhere, it is said to be collected and left to inspissate in wooden vessels. Collins remarks that, if the incisions be allowed to penetrate too deeply, they liberate a gummy substance, which, mingling with the rubber, depreciates its value. These vines may be tapped for rubber when 3 years old. Christy suggests their cultivation in plantations, and annually cutting down the young shoots almost to the ground, then crushing the stems between rollers, and treating the whole mass with carbon bisulphide, which dissolves the rubber, but not (he says) the injurious gummy matter. The rubber of these vines is of fairly good quality when carefully prepared. It should be made in separate sheets or cakes, 1–2 in. thick and 6 in. or so in diameter. Iron or stone vessels are superior to clay for collecting the juice. The better kinds are said to be prepared with the addition of 3 per cent. of strong liquor ammoniæ. When any liquid is added in the preparation, the sheets must be very thin, to facilitate drying. This question of drying seems to have much to do with the quality of the rubber, and the inferiority of African to Para rubber is largely attributed to its being sent into commerce in a raw, green state, whence possibly also arises its disagreeable odour, generated by decomposition. The desirability of introducing the *Attalea excelsa*, for the purpose of employing its nut (the *urucuri*) in curing African rubber, as in Para (see p. 1661), has even been discussed; but the slow smoky fire from any oily nut would probably have the same effect.

Another important W. African plant is *Urostigma Vogelii*, with possibly some other species. The tree (20–30 ft.) grows near the sea, at elevations of 50–60 ft., but does not flourish in marshy ground. The natives pollard the trees at 10–12 ft., and cut back the branches, thus obtaining a free and regular flow of sap. The cuttings are easily propagated, and grow vigorously. The trees are tapped at about 5 years, by making slashes or incisions in the trunk; the juice is collected in vessels, inspissated by the use of acids, and made up into balls the size of a large orange. Though often sent in a dirty state, the rubber is of good quality, and said to be the best of the Liberian. The juice obtained from trees less than 5 years old is watery, and does not afford such good rubber. Christy considers this a desirable species for cultivation in the lowlands of S. India, Ceylon, Java, Sumatra, Penang, and Siam.

A considerable proportion of W. African rubber is obtained from a plant which Holmes has determined to be *Tabernæmontana crassa.* In Senegambia, the *anjouan* (*Vahea senegalensis*) contributes to the supply. In Sierra Leone, rubber is collected from *Ficus Brasii*; and some *Ficus spp.* yield it in Angola on the W. coast, and at Inhambane on the E. A specimen of rubber from the W. coast of Africa is attributed to an undescribed species of *Carpodinus*; and in Réunion, some is said to be derived from *Periploca græca.*

The rubbers sold under the general name of African, omitting Mozambique and Madagascar, occur as shapeless lumps ("knuckles") from the Congo; "negroheads" or "balls" of scrap, and smooth cakes, from Sierra Leone; "thimbles," "nuts," and "negroheads" from the Portuguese ports; "tongues" from the Gaboon; and "balls" from Liberia. The African rubbers are more adhesive and less elastic than the Para article, and command a lower price; the inferiority could be much reduced by an improved system of preparation.

Assam, Java, Penang, and Rangoon.—Assam rubber is derived almost entirely from *Ficus elastica*, a small portion being obtained from *Urostigma laccifera.*

Ficus elastica grows wild along the foot and in the low tropical valleys of the Himálayas, from the Mechi River on the Nepal boundary at 88° E. long., to the extreme eastern limit of Assam, in 79° E. long., as well as along the feet and in the valleys of the southern mountains of the Bramaputra valley, viz. the Patkye, Naga, Khasi Jynteah, and Garrow Hills. It is not abundant until east of the Bor Nuddi, where it is common in the forests at the feet of the hills in the Khaling, Buri-goma, and Kuriapara Duars, between the Bor Nuddi and Mura Dunsiri Nuddi; the rubber has been exported from these forests, which extend over about 40 sq. miles, as well as from the low valleys of the Bhutan Hills, immediately above them, and especially from the forests in the neighbourhood of the exit of the Nunai Nuddi in the Khaling Duar and the adjoining hills, and those between the Dimjany and the Ruta Nuddis. In the Chardwar forests, between the Mura Dunsiri or Ruta Nuddi and Borali River, the plant is abundant. Between the Bilsiri and Goboru Nuddis, it is found as far as 16 miles from the hills, but the drier climate renders the produce much less plentiful. In the Nowdwar forests, where the climate is less moist, only the rubber obtained from trees close to the hills is good. In the Chydwar forests, the trees are found only immediately along the foot of the hills. The plant may be seen in parts of Sikkim, in the moist but rocky side-valleys of the torrents that feed the Teesta and Mahanadi rivers. It is also very abundant in the moist forest of the northern rainy zone of Burma, beyond British territory. It flourishes best in a very moist climate and a mean temperature of 98° F. in the shade, but will not endure stagnant water about the roots.

The collection of the rubber in Assam is conducted under rigid restrictions in the case of all trees growing in the timber reserves, but cannot be enforced in the case of scattered trees. Immense forests of the trees existed on both banks of the Subansiri river, and on other streams, but the reckless treatment they received from native lessees of the forests caused their ruin. In 1876, the leasing of these forests ceased, but there is now little or no rubber left in the plains of the Lakhimpur district. It is estimated that the forest of Cachar could yield upwards of 2000 cwt. of rubber annually. One district in Assam, 30 miles by 8, is said to contain 43,000 trees, many of them being 100 ft. high. According to Murton, there is little doubt that this same plant, *Ficus elastica*, affords the *gutta-rambong* of the Malay Peninsula, produced in the interior of Perak and on the Patani side of the Peninsula.

The natives who tap the wild trees slash every part of them within reach with their *daos* or knives. The incisions on the lower part of the stem, and on the roots which run some 30–40 ft. on the ground, are 6–18 in. long, and are made diagonally through the bark and into the wood, in an elliptical form, measuring about 3 in. across the centre. The exudation from these wounds is received in holes dug in the earth, or in leaves folded conically; that from the smaller cuts on the upper branches is allowed to concrete on the spot. According to Collins, the yield of a tree in August is about 50 oz. of milk, giving 15½ oz. of rubber; sometimes the proportion of rubber falls so low as 10 per cent. He also observes that "during the cold season, October–March, the milk is scantier, but richer than in the warm weather, March–October." Mann finds the best tapping season in Assam to be February–April. Hunter states that the trees "yield most during the rains;" he adds that a high yield for the first tapping of a tree 18 in.–6 ft. in girth is 35–40 lb. of rubber, it is then allowed 3–4 years' rest, when a second but much smaller collection is made.

Markham asserts that the trees may be tapped at 25 years, and that after 50 years they will yield 40 lb. of rubber every 3rd year. Murton says that in the Malay Peninsula the milk is obtained from the large roots, which are tapped 10–12 times in a year; a *picul* (133⅓ lb.) is sometimes taken from a large tree, but the usual yield is about ½ *picul*. This kind is said to require no preparation for market, and to present the appearance of long strings irregularly welded together, the best quality being gummy-looking, of very firm texture, and reddish-brown colour, while the inferior qualities have a large admixture of bark, and are much drier, without the gum-like consistence of the better grades. In Assam, on the other hand, it is the "loaf" rubber obtained from the lower parts of the stem and roots that requires artificial preparation, while none is bestowed upon the produce of the smaller branches. The treatment consists in pouring the milk into boiling water, and stirring until it assumes sufficient consistence to admit of being handled without becoming clammy or sticky. The plan adopted by a European house at Tezpore is to run the milk into wooden bins 6 ft. sq., partially filled with water, on which the rubber floats after a time. The latter, while still liquid, is removed and boiled over a slow fire in iron pans 4–6 ft. diam., and 2–2½ ft. deep, 2 parts of water being added, and the whole stirred constantly. When coagulated, the rubber is removed with iron forks, pressed, again boiled and pressed, sun-dried, and washed over with lime.

The rapid destruction by the natives of the wild rubber trees in Assam has called forth efforts to establish their cultivation in regular plantations. That at Chardwar has an area of 80 sq. miles, some 700 acres being under cultivation already. In 1878, it was stated that the planting had scarcely emerged from the experimental stage, for though no doubt remained that the tree would grow luxuriantly in the locality chosen, there was much variation in the degree of success gained by the several methods of planting. The plants put out in cane baskets in the forks of trees, though alive and healthy, remained nearly stationary; and many of those simply planted in the ground also did badly, thus condemning these two plans. All those planted on low split stumps, in earthenware cylinders on low stumps of trees, on piles of wood put crossways and mixed with earth, and on small mounds of earth 2–3 ft. high, did remarkably well, drainage about the roots being ensured by these modes. It has been proved that the best cuttings do not transplant so well as seedlings, and that raising plants from seed will be the method of propagation to be chiefly depended on.

Assam rubber has a peculiar mottled appearance, and varies in colour from cream or flesh tints to bright pink or reddish; it is very glossy, and sometimes covered with a greyish-white film, which may arise from oxidation or from some foreign application. Its form is either that of irregular lumps ("slab" or "loaf") produced as already described, or "balls" of the unprepared stringy substance obtained from the smaller branches. The impurities (bark, sand, clay) often reach 35 per cent., especially in the "balls." It arrives in baskets made of split rattan, covered with gunny-sacking, and weighing about 3 cwt. each.

Java rubber is also obtained from *Ficus elastica*, according to De Vrij. It is prepared by allowing the milk to concrete in the incisions made in the tree. It closely resembles Assam rubber, but has a deeper tint, with occasional reddish streaks.

Penang rubber is presumably identical in origin, no evidence being forthcoming in support of Wallich's statement that it is afforded by *Cynanchum ovalifolium*.

Rangoon rubber is also attributed to a *Ficus*, probably *F. hispida*.

These three kinds may be classed with Assam rubber for all technical purposes.

Attention has recently been called by G. W. Strettell to a troublesome climbing "weed," *Urceola* [*Chavannesia*] *esculenta*, very common in the Burmese forests, as a valuable source of rubber. It is urged that its cultivation could be made highly profitable. Assuming the plants to be placed 30 ft. apart, 400 acres would contain 19,200 of them, which are estimated to yield 1 *viss* (3 lb. 2 oz.) each per annum, worth 20*l.* per 100 *viss*, or 3840*l.* It is supposed that the cost of starting the plantation would be trifling, not exceeding 8*s.* per acre per annum on the first 7 years, making a total for that period of 1120*l.* The further cost of tapping, pressing, and preparing the juice is placed at 12½ per cent. of the profits, leaving a nett asset of over 3000*l.* per annum. The milk is said to coagulate more readily than that of *Ficus spp.* The incision adopted by Strettell is arrow-like, and made on the sides of the stem. The rows of cuts are 3 ft. apart, and arranged to be in vertical lines. Funnels formed of the leaves of *Butea frondosa* are selected for catching the exudation. The best season for tapping is about the end of April; between October and March, circulation is slow and the milk is scarce, but during the rains, the milk is more watery and abundant.

Borneo.—The sources of Bornean rubber are not very accurately known. One authority names as the chief plant *Urceola elastica*, a climber with a trunk as thick as a man's body, and a soft thick bark, capable of being tapped at 3 years, and soon shooting up after having been cut down. Of this, Burbidge specifies 3 varieties, known respectively as *petabo*, yielding the best rubber, *menungan*, the most prolific, and *serapit*, giving the lowest quality. On the other hand, the *petabo* plant has been identified at Kew as a *Leuconotis sp.* Again, Burbidge himself more recently writes that the Bornean rubber or *gutta-susu* is the mixed saps of 3 species of *Willughbeia*, with the milks of 2 or 3 other plants surreptitiously introduced to increase the quantity; and he gives the Malay names of the 3 species as *manungan*, *manungan puti*, and *manungan manga*. Their stems have a length of 50–100 ft., and a diameter rarely exceeding 6 in. He adds that they are being slowly but surely exterminated by the collectors in Borneo, as throughout the other Malay islands, and on the Peninsula, where they likewise abound; on the other hand, they grow rapidly, and readily lend themselves to both vegetative and seminal methods of propagation, and hence are especially deserving of the attention of the Government of India, where they may reasonably be expected to thrive. The stems of these creepers are cut down to facilitate the collection of the creamy sap, being divided into sections measuring a few inches to 2–3 ft. long; the escaping milk flows into jars or buckets, the exudation being sometimes hastened by applying heat to one end. When sufficient sap has been thus collected, it is coagulated into rough balls by the addition of salt water or nipa salt (the latter obtained by burning the foliage of the *nipa* or *susa* [*Nipa fruticans*]). It reaches Liverpool in porous or spongy balls and shapeless lumps, internally white or pinkish, and saturated with salt water in such quantity as to cause a loss of 20–50 per cent. in weight on drying.

Burbidge remarks that there are many milk-yielding species of *Ficus* in the Bornean forests, which, with careful experiment, may possibly be made to contribute remunerative quantities. The Malayan representatives of the *Artocarpeæ* also deserve examination.

According to Murton, the *gutta-sing-garip* of the Malay Peninsula is identical with the *gutta-susu* of Borneo. There are two varieties of the plant producing it: one has a very dark-coloured outer bark, with lighter-coloured warts, and red inner bark; the other has a light cork-coloured outer bark, with longitudinal channels, and light-yellow inner bark. The produce of the former is considered superior. The stems are sometimes cut down, but are generally ringed at intervals of 10–12 in., and the milk is allowed to run into vessels made of palm-leaves or coco-nuts; the flow continues for some time, but after 10 minutes, the substance is very watery and thin. One plant will yield 5–10 *catties* (of $1\frac{1}{3}$ lb.) of coagulated rubber. When raw, the juice has the appearance of sour milk; it is coagulated by the addition of salt or salt water, and resembles Bornean *gutta-susu* in all respects.

Ceara.—The rubber known in commerce as "Ceara scrap" is produced by a distinct species from the other Brazilian and Central American rubbers, which has been named *Manihot Glaziovii*. It is a tree of 30 ft. in height, with a dense rounded crown, and attaining a diameter of 4–5 in. in 2 years. It grows wild in the flat country of Brazil running inland from the coast-town of Ceara, in 4° S. lat., mostly, so far as is known, at an altitude of about 200 ft. The district possesses a very dry arid climate for a considerable portion of the year; the rainy season lasts from November to May–June, when torrents of rain fall for several days in succession, followed by fine weather. There are years when scarcely any rain falls. The daily temperature averages about 82°–90° F. The soil frequented by the tree is sandstone, gravel, or granite, its dryness and poverty being indicated by absence of all ferns, weeds, grasses, and mosses.

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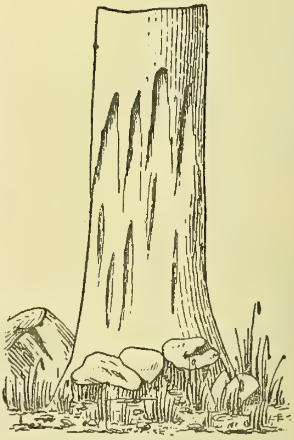


The native system of bleeding the trees and collecting the rubber is sufficiently simple. The collector commences by sweeping away loose stones and dust from around the foot of the tree, and spreading some large leaves to receive the milk as it flows from the tree. The outer surface of the bark of the trunk is then stripped off to a height of 4–5 ft., as shown in Fig. 1173, and the milk exudes and runs down in many tortuous courses, a portion usually falling upon the ground. After several days, the juice becomes dry and solid, when it is pulled off in strings and rolled up in balls, or put into bags in loose masses. The paring should only be deep enough to reach the milk-ducts, which reside in the middle layer of the bark; but this circumstance is seldom regarded by the collectors, and many trees are prematurely destroyed by the careless wounding of the wood. The operation is conducted only during the dry season.

The habits and habitat of this plant immediately pointed it out for cultivation in a systematic manner in some of our warmer possessions, and the success attending the experiments is the more desirable since the late drought in Brazil caused the death of immense numbers of the tree. It has proved itself to be well adapted for culture in Ceylon, Upper India, Zanzibar, and Jamaica, but the climate of the Malay Peninsula is too moist for it. The experience gained thus far in its cultivation may be briefly stated. Seeds are early produced, if the tree is not shaded. They should be buried in brown sand, and kept moist until there are indications of growth, when they may be planted out permanently. In some situations, where the ground is rough and strong, they might be sown broadcast. Plantations may also be formed by cuttings, which take root as easily as a willow. They should be from the points of strong shoots, and about 1 ft. in length. In planting, each cutting may be put down in the soil to a depth of 6 in. If scarce, the entire shoot may be cut into pieces, each possessing a bud, all of which will grow if covered with ½ in. or so of soil. On loose sandy soils, or exhausted coffee land, plantations may be formed at little expense. Hard, dry, gravelly wastes, if found to support any kind of bush, are also suitable sites. Holes might be made in strong land with an iron jumper, and a stout cutting put into each, and filled with pebbles. On bare or thinly covered portions of rock, the cuttings might be laid down flat, and a little heap of stones, or any kind of débris, about the size of a mole-hill, piled over each, care being taken that the extreme point of each cutting with a bud is left uncovered. Wherever there is any sort of stunted tree or shrub vegetation, with an occasional sprinkling from a monsoon shower, the tree is likely to prosper. There can be no doubt of the hardiness of the species, its readiness of culture, and adaptability to circumstances. It grows quite as readily from seed as from cuttings, and, though a native of a tropical sea-level, thrives well in Ceylon up to at least a level of 3000 ft., and on the most barren soils. It would seem especially adapted for the dry and barren districts of the E. and N. provinces of Ceylon, or in the higher districts; but it would not be wise to risk it in localities where the temperature is liable to fall below 60° F.

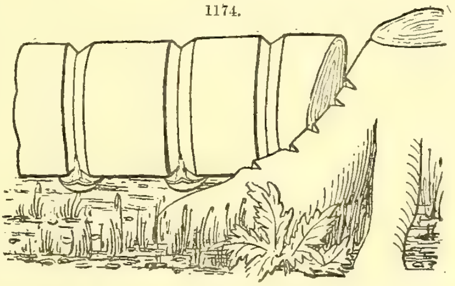
The seed-coat is of remarkable thickness, and very hard, and the natural process of germination occupies, it is said, more than a year. All that is necessary to hasten this, is to assist the seed-coat in splitting, which is best effected by holding the seed firmly, and rasping off with a file both edges at the radicular end, recognized externally by possessing at its side a flat two-lobed appendage, technically known as the caruncle. It is best not to file off the actual end, as the radicle of the embryo may then be injured. After this treatment, properly performed, the young plant appears above ground in 2–3 weeks. The seedlings require no particular attention. They grow rapidly, and may be finally planted out at distances of 20 ft. The trees at Peradeniya (Ceylon) flowered at the age of 18 months; at 2½ years, the larger ones formed branching trees about 25–30 ft. high, with a stem 1 ft. 9 in. in circumference, at a yard from the base, and a smooth, silvery, birch-like bark, readily peeling off. The best system of tapping the trees under cultivation has yet to be proved. Some improved methods are described later on in the present article (see p. 1666).

This rubber is considered almost next to Para in value, being dry, very elastic, and free from stickiness; its one drawback of containing wood and other foreign matters, in such quantity as to cause a loss of often 25 per cent. in washing, may doubtless be altogether removed by the exercise of care in the collecting.

Central American.—The Central American, Cartagena, and Guayaquil rubbers are yielded chiefly by the *ulé* (*Castilloa elastica*), a lofty tree with a trunk 8 ft. diam., found in Mexico, Guatemala, Salvador, Honduras, Nicaragua, Costa Rica, Panama, the W. coast of S. America down to Guayaquil, and the slopes of Chimborazo, as well as in Cuba and Hayti. This extensive geographical range shows the tree to be capable of existing under considerably varied climatic conditions. The forests in which it grows are usually at or near sea-level, but it has been observed at an elevation of 1500 ft. on the Pacific coast. The soil is various, but the tree avoids marshy or boggy land, and manifests a preference for warm, deep loam or sandy clay, and it especially affects the margins of small running streams, where it occurs in little groups. A moist climate and high equable temperature are essential; the trees thrive best in dense, steaming, hot forests, and are particularly abundant where it rains during 9 months of the year, and the temperature ranges between 75° and 88° F. A second smaller species, *C. Markhamia*, also occurs in Panama.

In Panama, the usual method of collecting the milk is by felling the tree, and then making deep notches around the trunk at distances of about 1 ft. apart, as shown in Fig. 1174. Broad leaves placed beneath the notches receive the milk, which is afterwards collected in a large calabash or other vessel, poured into a hole in the ground, and thatched over with leaves, where it coagulates in about 2 weeks. Another plan is to bruise a handful of the leaves of the *Ipomœa bona nox*, and stir them about in the milk, which is thereby thickened in about an hour to a jelly-like porous mass, profusely exuding a black ink-like water when touched. The article thus produced is inferior. It is sometimes sliced into flakes 1 in. thick and sun-dried. In Nicaragua, it is found

1174.



that though the tree yields the juice at all seasons, the best time for tapping is April, when the old leaves begin to fall and the new ones appear. During the rainy season, May–September, the richness of the juice diminishes. From that time till January, the rains decrease, the milk increases in richness, the tree prepares to flower, and the fruit appears in March, during which month and the succeeding one the milk contains the greatest proportion of rubber, the difference amounting to 60 per cent. more in April than in October. A tree about 18 in. diam. (probably 6 years old) tapped skilfully in April will yield some 20 gal. of milk capable of giving 50 lb. of rubber. This is a maximum figure, and the average is somewhat less. A tree of 20–30 ft. to the first branches is expected to afford 20 gal. of milk, and each gallon of milk to render 2 lb.–2 lb. 2 oz. of good dried rubber. By the Panama system of destroying the tree, the produce often amounts to 100 lb. of rubber from a tree. The Nicaraguan mode of tapping is as follows. The collector ascends the tree by climbers or a ladder as high as possible, and then commences a series of incisions with a sharp *machete* or axe in one of two ways. One is to make a long vertical cut, with diagonal cuts running into it, as in Brazil; the other is by encircling the tree with spiral cuts at an inclination of 45°; if the tree be large, two such spirals are made, either crossing or parallel with each other. At the bottom of the trunk, an iron spout is driven in, and the milk is received into iron pails. In the evening, the milk is freed from foreign matters by passage through a sieve, before transference to the barrels in which it undergoes coagulation. This last condition is brought about by the addition of plant-juices, notably that of the *acheté* (*Ipomœa bona nox*), as in Panama. The plant is collected, moistened with water, and bruised, and the juice, after straining, is added to the milk, in the proportion of 1 pint to 1 gal. After this operation, the rubber appears as a soft mass floating in a brown fluid, and smelling like new cheese. The mass is pressed under a plank or iron roller into a *tortilla* or cake, usually weighing about 2 lb. when dry, and representing 1 gal. of milk. When the *acheté* or other suitable plant is not procurable, water in the proportion of 2 to 1 is added to the milk, and the whole is allowed to stand for 12 hours. The residue which separates from the water is poured into underground vats and left to dry for 12–14 days. Sometimes the milk is simply poured on a prepared spot of ground, and the watery portion left to evaporate or disappear as it may; the rubber, when outwardly dry, is pressed to remove *bolsas* or bubbles of watery liquid. Slabs made in this way are sometimes called *méros*. The rubber which is allowed to dry in the iron spout conducting from the tree trunk is rolled into balls, and called *cabezza*; that which dries in the wounds on the tree is termed *bola* or *burucha*, and is esteemed in New York. The loss by drying (*merma*) is estimated at about 15 per cent. A recent traveller in Central America states that the *ulé* tree "yields many gallons every 2 years;" but in Panama, the tree is totally destroyed in obtaining the milk, and elsewhere the tapping is said to be so injuriously done as to be little better than immediate destruction.

There are several commercial varieties of the rubber obtained from *Castilloa spp.* Cartagena rubber arrives from New Granada (Colombia) in black sheets ¾ in. thick, having a somewhat rough or "chewed" appearance, and more or less "tarry" or sticky. It also occurs in strips or scraps pressed together in bags. It loses about 35 per cent. of its weight on drying. Guayaquil rubber comes from Ecuador in large flakes and lumps, the better quality being whitish coloured, while the inferior is porous and saturated with a fœtid black liquid. Its loss by washing sometimes reaches 40 per cent. This and the preceding kind go chiefly to America. Nicaragua rubber, which mostly reaches the same market, loses only 15 per cent. by drying. The best of the Central American rubbers is that known as "W. Indian," not from its being produced in the W. Indies, but coming in steamers sailing thence. It consists of blocks which, in the first quality, are formed of thin separable sheets, and, in the second, of conglomerated "scraps" with fragments of bark. Honduras rubber is of good quality, and free from "tarry" matter. Guatemala rubber is one of the lowest and least regular kinds; the best specimens are whitish, while the "lower" are black and "tarry." This rubber arrives in sheets compacted together, whence a thick resinous fluid exudes on pressure; this fluid, on evaporation, leaves a hard resinous substance unaffected by steam.

The wasteful and destructive local methods of collecting the milk of this genus are causing its rapid extermination in the countries where it is indigenous. Attention has been directed to its naturalization in our tropical possessions, but though the plant is of rapid growth, it will scarcely thrive in regions that are not equally suited to the *Hevea spp.*, and its rubber is much inferior. It has been introduced successfully in Ceylon, Singapore, and Perak. With regard to its culture, it may be observed that trees in good situations will produce seeds early, but these need to be planted without delay, as drying destroys their vitality. Flowering occurs in January, and the fruits ripen in April (in Brazil). Stout branches, cut into pieces, each possessing a bud, and covered lightly with soil, will generally be found to grow. Strong cuttings 1 ft. long and furnished with buds, planted in the usual way, sooner develop strong plants. But the propagation of this tree is not reckoned so easy as that of the Ceara rubber (*Manihot Glaziovii*). In setting out young plants, the petiole or leaf-stalk of the lowest or oldest leaf should be buried in the soil; this simple device ensures the immediate and vigorous growth of the plant, and a symmetrical stem. When the planting leaves much bare stem above ground, the growth is slow, the plant long remains "leggy," and never forms a good tree. The plant has the curious habit of dropping its young branches, which disarticulate by a regular joint, and leave a clean scar on the surface of the stem. It is believed that after 6 years, the trees might be judiciously bled every 3 years.

Para.—Para rubber, which is second to none in importance, is afforded by several species of *Hevea* [*Siphonia*], the most important being *H. brasiliensis*, *H. guianensis*, and *H. Spruceana*. These trees inhabit the dense, steaming forests on the Amazon and its tributaries, other species replacing them in some of the adjacent countries, e. g. *H. paucifolia* in British Guiana, where Prestoe believes it will be found in considerable abundance. Brazil is being gradually but surely denuded of its rubber-trees, collectors being now driven to the Tocantins, Madeira, Purus, and Negro rivers in search of supplies. A recent traveller states that, in Bolivia, extensive rubber forests are at present profitably worked on the Lower Beni, and it is natural to suppose that they exist to an equal extent on the Mayutata and Aquiry; those on the Mamoré and Lower Itenez, though giving rubber of a superior quality, do so in less quantity.

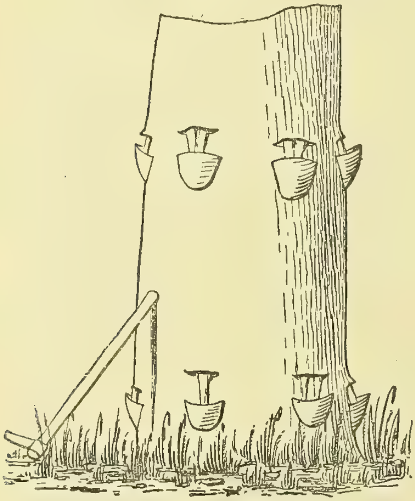
In the Para district of the Lower Amazon, the temperature varies between 74° and 95° F., the mean of the year being 81° F.; the supply of moisture is also very regular. On the Upper Amazon, the atmosphere is densely vapour-laden. The soil frequented by these trees is extremely rich mould. The trees will grow on the *terra firme* when planted, but their seeds naturally lodge in lowland swamps. All the species flourish best on rich alluvial clay slopes by the side of running water, where there is a certain amount of drainage; those growing on land which is periodically inundated (even to a depth of 5 ft.) are more prolific than those on very low or on elevated ground.

The methods adopted for tapping the trees are described at length by Cross. The collectors begin work immediately at daybreak, or as soon as they can see to move about among the trees. Rain often falls about 2–3 o'clock in the afternoon, so the tapping must be done early, as in the event of a shower, the milk would be spattered about and lost. The collector, first of all, at the beginning of the dry season, goes round and lays down at the base of each tree a certain number (3–12) of small cups of burnt clay. On proceeding to his work, the collector takes with him a small axe for tapping, and a wicker basket containing a good sized ball of well-wrought clay. He usually has likewise a bag for the waste droppings of rubber, and for what may adhere to the bottoms of the cups, these promiscuous gatherings being termed *sernamby*, and forming the "negro-head" of the English market. The cups are sometimes round, but more frequently flat or slightly concave on one side, so as to stick easily, when, with a small portion of clay, they are pressed against the trunk of the tree. The contents of 15 cups make about 1 pint. Arriving at a tree, the collector takes the axe in his right hand, and, striking in an upward direction as high as he can reach, makes a deep upward sloping cut across the trunk, which always goes through the bark, and penetrates 1 in. or more into the wood. The cut is 1 in. in breadth. Frequently a small portion of bark breaks off from the upper side, and occasionally a thin splinter of wood is also raised. Quickly stooping down, he takes a cup, and pasting a small quantity of clay on the flat side, presses it to the trunk close beneath the cut. By this time, the milk, which is of dazzling whiteness, is beginning to exude; if requisite, he smooths the clay so that the milk may trickle directly into the cup. At a distance of 4–5 in., but at the same height, another cup is luted on; and so the process is continued, until a row of cups encircle the tree at a height of about 6 ft. from the ground. Tree after tree is treated in like manner, until the tapping required for the day is finished. This work should be concluded by 9–10 o'clock in the morning, because the milk continues to exude slowly from the cuts for three hours, or perhaps longer. The quantity of milk that flows from each cut varies; but if the tree is large and has not been much tapped, the majority of the cups will be more than half-full, and occasionally a few may be filled to the brim. But if the tree is much gnarled from tapping, whether it grows in the rich sludge of the *gapó* (inundated land) or on dry land, many of the cups will be found to contain only about a tablespoonful of milk, and sometimes hardly that. On the following morning, the operation is performed in the same way, only that the cuts or gashes beneath which the cups are placed are made 6–8 in. lower down the trunks than those of the previous day. Thus each day brings the cups gradually lower, until the ground is reached. The collector then begins as high as he can reach, and descends as before, taking care, however, to make his cuts in separate places from those previously made. If the yield of milk from a tree is great, two rows of cups are put on at once, the one as high as can be reached, and the other at the surface of the ground; in the course of working, the upper row descending daily 6–8 in., while the lower one ascends the same distance, the rows in a few days come together. When the produce of milk diminishes in long-wrought trees, two or three cups are put on various parts of the trunk, where the bark is thickest. Although many of the trees of this class are large, the quantity of milk obtained is surprisingly little. This state of things is not the result of over-tapping, as some have stated. Indeed, Cross believes it impossible to overtap a tree, if, in the operation, the wood is not left bare or injured. But at every stroke, the collector's axe enters the wood, and the energies of the tree are required in forming new layers to cover those numerous wounds. It has been supposed that the quality of the milk is better in the dry season than during the rains. In the rainy season, the milk probably contains a greater proportion of water; but, on the other hand, a larger quantity of milk then flows from the tree. No doubt the dry season is the most suitable for rubber collecting, although, wherever a plantation is provided with a preparing-house, convenient tapping may certainly be always carried on when the weather is fine. It is a common report that the trees yield the greatest quantity of milk at full moon. Even if this were found to be true, it would probably make little difference, as tapping must be carried on when circumstances are most favourable.

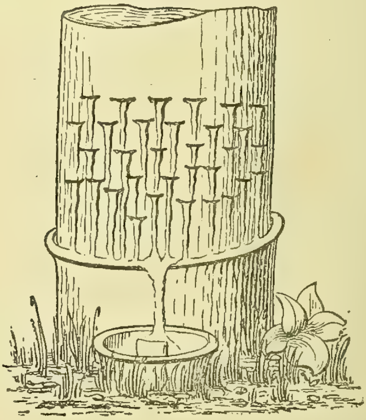
There are two other methods adopted in tapping, which are chiefly confined to the Upper Amazon and its tributaries. Both are exactly on the same principle, the materials used being only a little different. The loose outside bark of the tree is cleaned off to a height of about 3 ft. Beneath, a gutter or raised border of clay is pasted or luted to the trunk, enclosing one-half or the entire circumference. Cuts are thickly made in the bark above this, from which, the milk flows down to the gutter, whence it is conveyed to fall into a calabash conveniently placed. The other mode is by winding round the trunk the stout flexible stem of a climber, and claying it round securely so that no milk may escape between the trunk and the climber. These plans are not extensively adopted, and can only be successfully put in practice where the trees have not been previously tapped. There is always a great deal of "negrohead," the result of the distance the milk has to run, and of the large quantity of clay employed in the process. The respective methods are illustrated in Figs. 1175, 1176, 1177. Fig. 1178 shows the exhausted tree in a state of decay.

Going from tree to tree, the collector empties the contents of the cups into a large calabash, which he carries in his hand. As he pours the milk out of each cup, he draws his thumb or forefinger over the bottom to clean out some which otherwise would adhere. Indeed, a small quantity does remain, which is afterwards pulled off, and classed as *sernamby*. The cups, on being emptied, are laid in a little heap at the base of each tree, to be ready for the following morning. The trees occur at various distances (10–100 yd.) apart, and it is surprising that the natives have not yet seen the advantages that would be derived from forming plantations, whereby more than twice the quantity of rubber might be collected in one-fourth the time, and at far less cost and labour.

1175.

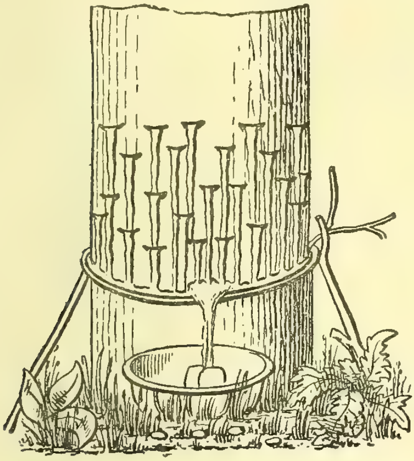


1176.



The common method of preparing the rubber is represented in Fig. 1179. The jars *a* are 18 in. high, and the bottoms are broken out. At the base, they are 7 in. diam., bulging out in the middle to 12 in., and narrowed at the mouth to a breadth of 2 in. Where a number of men are collecting for one master, much larger jars are in use. The milk, on being put into a large flat earthen vessel *b*, is placed on the floor in a convenient position. Adjacent thereto, the jar is set on three small stones, which raise it to 1½ in. above the floor. The narrow space between the base of the jar and the floor allows the entry of air, which causes a current of smoke to ascend with remarkable regularity and force. When the fire commences to burn strongly, several handfuls of nuts (preferably *urucuri* [*Attalea excelsa*], but failing them, those of *Euterpe edulis* and other palms), are put on, then some more wood and nuts alternately. The latter are dropped in at the mouth of the jar, until it is filled to within 4 in. of the top. Due care is taken that a sufficient proportion of wood is put in with the nuts. The mould *c* on which the rubber is prepared resembles the paddle of a canoe; in fact, at many places on the Amazon, this is the article most frequently used, if there is much milk, and the rubber is prepared in bulky masses. Occasionally the mould is slung to the roof, as the weight in handling it during the process would otherwise be very fatiguing. A little soft clay is rubbed over it to prevent the rubber from adhering, and it is afterwards well warmed in the smoke. The operator holds the mould with one hand, while with the other he takes a small cup and pours two or three cups of milk over it. He turns it on edge for a few moments above the dish, until the drops fall, then quickly places the flat side 2 in. above the jar mouth, and moves it swiftly round, as if describing the form of a cipher, with his hand, so that the current of smoke may be equally distributed. The opposite side of the mould is treated in the same way. The coating of milk on the mould, on being held over the smoke, immediately assumes a yellowish tinge, and although it appears to be firm on being touched, is yet found to be soft and juicy, like newly-curdled cheese, and to be sweating water profusely. When layer after layer has been repeated, and the mass ("biscuit") is of sufficient thickness, it is laid down on a board to solidify; in the morning, it is cut open along the edge on one side, and the mould is taken out. "Biscuit" rubber, when fresh, is often 4–5 in. thick. On being hung up to dry for a few days, it is sent to market. The rapid coagulation of the milk seems to be simply produced by the high temperature (about 180° F.) of the smoke. Cross thinks that with a strong current of heated air, or a good pressure of steam from a pipe, or by putting the milk in shallow vessels, and evaporating the moisture by the heat of boiling water, a similar result would be obtained. The finely divided

1177.



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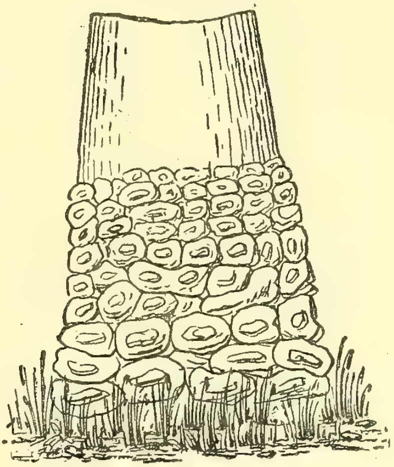

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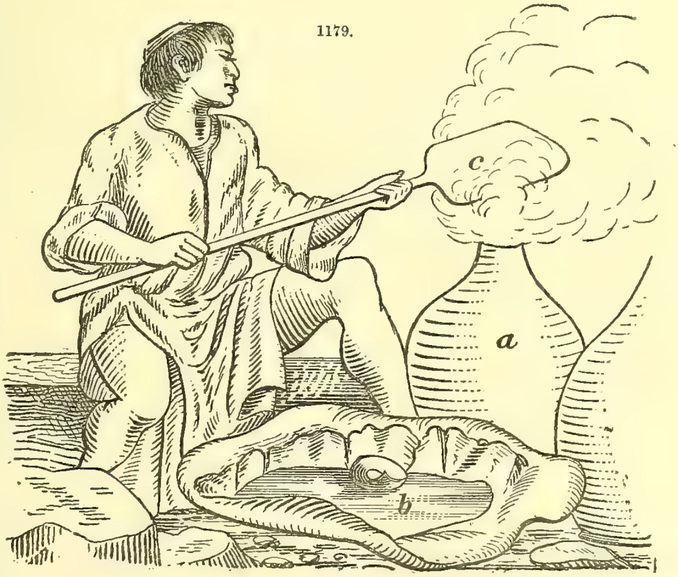


particles of soot which form a large proportion of the smoke undoubtedly absorb a considerable amount of moisture, although at the same time forming an impurity.

A more modern method of preparing the milk is by treatment with an aqueous solution of alum, and subjecting the coagulated mass to pressure, in accordance with Strauss' proposition. This plan is said to be in favour, as being capable of performance at a distance from the unhealthy locality where the milk is produced. The proportion of alum solution required is very small, but varies with the character of the milk. The latter should be previously strained free from extraneous matters. Coagulation ensues in 2–3 minutes. The rubber is then exposed to the air on sticks, and allowed to drain for 8 days. It is sometimes subjected to expression. The drawback of the process is the "wetness" which the rubber acquires from the presence of saline particles, which are never completely removed by pressing.

The excellent quality of this rubber has commended the plant to the attention of agriculturists in India and elsewhere. The result of experiments hitherto seems to be favourable to its establishment in Ceylon, Malabar, S. Burma, Zanzibar, and Jamaica, but not in Central and N. India.

The propagation and planting may generally be combined in one operation, the object being to reduce the expense, simplify and accelerate the work, and promote the more perfect development of the primary roots and trunk. The green-coloured terminal shoots of succulent growth, with the leaves fully matured, make the best cuttings. These should be cut off low enough, so that there is a joint at the base. When it is desirable to plant in dry firm land, a spadeful of soil should be turned over at each place, and the cutting planted in a sloping position. It should be covered with mould to within 3 in. of the point. The portion above ground should rest on the earth on one side of its termination, so as not to suffer during hot sunshine. In all stages, the crowns of the plants may be exposed to the rays of the sun. Plants intended for cutting stocks may be planted in open places, in the richest dark loam capable of producing a luxuriant rank crop of sugar-cane. Seeds might be planted out permanently at once, also in the same way as the cuttings. These would prosper much better if at the time of planting a handful of wood-ashes were added to the soil with each seed. Good ashes may be obtained by the burning of any description of green wood or newly-felled piece of forest. If the wood is allowed to rot before burning, almost the whole of the fertilizing principle will be found to have vanished. If stored in a damp place, the value of the product is diminished. For planting on inundated lands, the period of high flood should be preferred. Cuttings of greater length would be required in this case, the lower end of which should be sliced off in the form of a wedge. The workman could take a bundle of these, and, wading into the water, would plant at proper distances, but perfectly upright, taking care to push each cutting down deep enough in the soft muddy bottom, so that not more than 3–4 in. is above the surface of the water. The same rule would be applicable when planting in sludge or soft marsh land. The crowns of the cuttings must not, if possible, be put under water, as the young growths springing therefrom might rot. Seeds will not be found very applicable for planting in watery places or deep mud deposits. Some would come up, but a good many would mould and decay. In the varied course of circumstances and conditions, slight changes and modifications in the methods of working will no doubt suggest themselves.

Para rubber occurs in commerce in two forms:—"biscuits," prepared as described on pp. 1622–3, containing about 15 per cent. of water; and rounded balls of "negrohead," containing 25–35 per cent. of woody fragments, and other impurities. Occasionally an intermediate quality called "entrefine" appears. Adulteration is sometimes practised by the addition of the juice of the cow-tree or *massaranduba* (*Mimusops elata*).

PERNAMBUCO OR MANGABEIRA.—The *mangaba*, *mangabeira*, or *mangabiba* tree (*Hancornia speciosa*), a native of the high plateaux of S. America, between 10° and 12° S. lat., at 3000–5000 ft. elevation, affords a kind of rubber. The inhabitants of Pernambuco are now developing the supply of this article, which is collected by making oblique cuts penetrating the bark round the trunk, and attaching receptacles thereto. The juice is coagulated by Strauss' method (see above), and after 30 days' drying, is sent to market in cases and barrels. It occurs in the form of "biscuits" and "sheets." Like all rubber coagulated by saline solutions, it is very "wet," and does not rank high in value. It may be remarked that these trees do not seem to have suffered from the recent droughts in Brazil. Further, that the rubber might be much improved in quality by a better method of preparation.

OTHER RUBBERS.—There are a few other rubbers which are prepared as articles of commerce, but as yet scarcely known in British markets. "Palay" rubber is obtained from *Cryptostegia grandiflora*, a common plant on the coast of India. In Chittagong, it is furnished by *Willughbeia edulis* and *W. martabanica*. Sumatran rubber is yielded by *W. prima*, and is exported to Holland. Malacca rubber is ascribed to *Urceola elastica*. The rubber of the Malay Archipelago is attributed to *Alstonia costulata* and *A. scholaris*; and Fijian rubber is produced by *A. plumosa*. In N. Australia, rubber has been procured from *Ficus macrophylla* and *F. rubiginosa*; the latter is hardy, and has been recommended for culture.

Many other plants afford juices which coagulate on exposure, and bear more or less general resemblance to indiarubber. They may possibly be utilized when better known. They are chiefly as follows:—*Ficus anthelmintica*, the *cuaxinduba* of Brazil; *F. Doliaria*, the *copaub-uçu* of Brazil; *F. elliptica*, of S. America; *Cecropia peltata*, of Tropical America; *Artocarpus incisa*, the bread-fruit tree, in Malaysia and Oceania; *Galactodendron* [*Brosmium*] *utile*, in S. America, especially Venezuela; *Lactaria calocarpa* and *L. Moorei*, of New South Wales and Queensland; *Tabernæmontana spp.*, in New South Wales, Queensland, and Malaysia; *Plumaria phagædænica*, the *súcuúba* of Para (Brazil); *Cameraria latifolia*, in Cuba; *Gymnema lactiferum*, of Ceylon; *Chrysophyllum spp.*, of Brazil; *Sideroxylon spp.*, of Malaysia; *Kakosmanthus macrophyllus*, of Java; *Imbricaria coriacea*, of Mauritius, Madagascar, and Java; *Ceratophorus spp.*, of Malaysia; *Macaranga tomentosa*, of the E. Indies; *Sapium scoparium*, of the Antilles; *Hippomane Mancinella*, of Tropical America; *Euphorbia corollata*, in Canada.

Commerce.—The commerce in rubbers, which may be said to be a growth of the last 25 years, has now attained great importance. Our imports of indiarubber (termed "caoutchouc" in the Returns) were 158,692 cwt., value 1,536,660*l.*, in 1876; 159,723 cwt., 1,484,794*l.*, in 1877; 149,724 cwt., 1,313,209*l.*, in 1878; 150,601 cwt., 1,626,290*l.*, in 1879; 169,587 cwt., 2,387,947*l.*, in 1880. The imports of 1880 were contributed as follows:—Brazil, 76,466 cwt., 1,297,373*l.*; W. Coast Africa, foreign, 22,922 cwt., 276,741*l.*; Straits Settlements, 11,582 cwt., 114,989*l.*; Bengal and Burma, 10,264 cwt., 114,416*l.*; E. Coast Africa, 9382 cwt., 129,886*l.*; W. Coast Africa, British, 7271 cwt., 86,669*l.*; Aden, 6720 cwt., 84,780*l.*; British S. Africa, 4620 cwt., 42,653*l.*; Portugal, 3871 cwt., 55,804*l.*; United States, 3799 cwt., 48,039*l.*; Central America, 2440 cwt., 29,005*l.*; Holland, 1576 cwt., 17,269*l.*; Mauritius, 1550 cwt., 19,927*l.*; New Granada (Colombia), 1024 cwt., 12,165*l.*; other countries, 6100 cwt., 58,251*l.*; total, 169,587 cwt., 2,387,947*l.* Our exports in 1880 were as follows:—United States, 21,941 cwt., 282,894*l.*; Germany, 18,921 cwt., 269,086*l.*; Russia, 16,189 cwt., 261,252*l.*; France, 9920 cwt., 112,597*l.*; Holland, 7182 cwt., 101,068*l.*; other countries, 2579 cwt., 36,878*l.*; total, 76,732 cwt., 1,063,775*l.*

A review of the fluctuations in the supplies during the past 5 years shows the following facts. Holland sent us 2651 cwt. in 1876, 1059 in 1878, and 1576 in 1880. Portugal: 3329 in 1877, 2285 in 1879, 3871 in 1880. Portuguese W. Africa: 3881 in 1877, 1822 in 1878, 5248 in 1880. Portuguese E. Africa: 617 in 1876, 131 in 1877, 1497 in 1880. Fernando Po: 241 in 1876, 52 in 1877, 277 in 1878, 117 in 1879, 248 in 1880. W. Coast Africa: 16,841 in 1876, 9632 in 1878, 17,426 in 1880. E. Africa (native states): 1263 in 1876, 7855 in 1880. Madagascar: 32 in 1876, 83 in 1877, nil in 1878, 110 in 1879, 501 in 1880. Borneo: 15 in 1876, none since direct. Central America: 5425 in 1876, gradually falling to 2440 in 1880. Mexico: 62 in 1876, 291 in 1878, 50 in 1880. New Granada (Colombia): 3398 in 1876, gradually falling to 1024 in 1880. Venezuela: 521 in 1876, 354 in 1877, 710 in 1878, 482 in 1879, 986 in 1880. Brazil: 80,828 in 1876, 90,917 in 1878, 76,466 in 1880. Gambia and Sierra Leone: 2827 in 1876, 5641 in 1877, 3808 in 1879, 7104 in 1880. Gold Coast: 585 in 1876, 12 in 1879, 167 in 1880. Cape: 774 in 1876, 2120 in 1877, 1431 in 1878, 4620 in 1880. Aden: 2494 in 1876, 1254 in 1878, 6720 in 1880. Mauritius: 1790 in 1876, 570 in 1879, 1550 in 1880. Bengal and Burma: 12,990 in 1876, 9260 in 1878, 10,264 in 1880. Straits Settlements: 7615 in 1876, 5436 in 1878, 11,582 in 1880.

The exports of Bornean rubbers are included under guttapercha (pp. 1653–4). Of Brazilian ports, Ceara, in 1878, sent 40,377 *kilo.* to England, 258 to Hamburg, and 74 to Havre. Panama (in Colombia) sent 23,128*l.* worth of rubber to the United States in 1879. Costa Rica exported 27,854 lb. of rubber in the year ending Apr. 30, 1879; the quantities in previous years had been 57,213 in 1875, 59,427 in 1876, 90,576 in 1877, 78,231 in 1878; the shipments from the port of San José in 1880 were 11½ tons, 2078*l.* Ecuador exported 7059 *quintals*, value 24,707*l.*, in 1877; 6561 *quintals*, 22,963*l.*, in 1878 (of which, 5853 went to the United States, and 708 to England); 5594 *quintals*, 33,564*l.*, in 1879; 7995 *quintals*, 59,972*l.*, in 1880; in 1873, the exports were 16,365 *quintals*. Guatemala, in 1879, exported 1873 lb. to Belize; the value was 262 dol.; in 1877, the value was 2723 dol. The exports from British India were 15,893 cwt., 108,645*l.*, in 1875; 15,258 cwt., 97,861*l.*, in 1876; 13,308 cwt., 90,169*l.*, in 1877; 13,794 cwt., 89,381*l.*, in 1878; 10,033 cwt., 61,685*l.*, in 1879. The exports from the Lakhimpur district in 1871 were 260 tons, value 8340*l.* Assam exported 11,000 *maunds* (of 82 lb.) in 1873, and Sikkim 700. The exports from Java were 704 *piculs* (of 135½ lb.) for the 1876 crop; 15 to Holland and 10 to Singapore for the 1877 crop; 47 to Holland and 15 to Singapore for the 1878 crop; 135 to Holland and 58 to Singapore for the 1879 crop. The values of exports of rubber from Madagascar to Mauritius have been 37,458*l.* in 1873, 21,452*l.* in 1874, 14,539*l.* in 1875, 9770*l.* in 1876, 4672*l.* in 1877. The Venezuelan exports were 2545 lb. in British vessels, and 53,403 lb. in American, in 1878; and 27,563 lb. in American vessels in 1879. Mozambique exported 443*l.* worth in 1873, 22,198*l.* in 1876, and over 50,000*l.* in 1879; the figures have now probably reached their maximum, until roads shall have been made into the interior.

Values.—The approximate relative market values of the principal commercial rubbers entering

London are as follows:—Para, fine, 2–3*s.* a lb.; negrohead, 1*s.* 6*d.*–2*s.* 6*d.* Central American, 1*s.* 6*d.*–2*s.* 6*d.* Assam and Pegu, 9*d.*–2*s.* 6*d.* Other E. Indian, 1*s.*–2*s.* 6*d.* Madagascar and Mozambique, 1*s.* 3*d.*–2*s.* 8*d.*

Suggested Improvements in Collecting and Preparing Rubbers.—The time of year at which the sap ascends to the flowers has an effect on the quantity of rubber yielded. Too frequent tapping causes each successive yield to be less rich in rubber and more watery, and permanently injures the trees. Judicious tapping has no ill result. As to the manner in which the tapping should be performed, this will vary somewhat according to circumstances. Some remarks on tapping and barking other kinds of tree will be found under cinchona (see Drugs, p. 803), manna (see Drugs, p. 817), and maple-sugar (see Sugar); also under Copaiba, Gurjun, Peru, Tolu, Turpentines, and Varnishes, in the present article. The Brazilian plan of a perpendicular incision, with oblique tributary cuts on each side, has much to recommend it. Paring the bark, after the Ceara method, might also be advisable. The one great object to be kept in view is the avoidance of injury to the cambium layer. This is best effected by using an implement which is so made that it can only just remove or penetrate the bark sufficiently deep to reach the laticiferous vessels, residing mostly in the *mesophlœum* or middle layer of the bark. A modification of the knife used in marking standing timber, with the addition of a shoulder to adjust the amount of penetration, and a long handle, would probably meet all requirements. A clean cut, as opposed to a ragged one, not only heals readily, but keeps the product free from woody impurity.

The collected milk should be coagulated as rapidly as possible, for decomposition soon sets in, and materially modifies the character of the article. Some of the milks keep much longer than others without undergoing great change, but the collection of the day would always be best dealt with during the same day. It is undoubted that an effectual evaporative process for removing the water will produce a better article than any of the saline solution methods. A convenient form for the prepared rubber is thin (1–2 in.) sheets, which are easily packed into bales, and enable the amount of impurity to be readily arrived at.

Jalap.—See Drugs, pp. 814–5.

Jumrasi.—This gum has been doubtfully referred to *Elæodendron paniculatum*, a native of India. It occurs in roundish tears of variable size, the majority not exceeding ½ in. diam., externally finely rugose, and minutely cracked, with a shining fracture, rather brittle, some tears almost colourless, others dark reddish-brown, with intermediate shades of amber and brown. It is tasteless, and soluble in water, forming a tenacious sherry-coloured mucilage. It is not an article of commerce, but deserves attention with that view.

Jutahy-seca, or S. American Copal.—The so-called S. American copal is said to be a product of several species of *Hymenæa, Trachylobium*, and *Vouapa*, but the great bulk of it is undoubtedly derived from the W. Indian locust-tree, the *algarroba* of Panama, *jutahy* of Brazil, and *simiri* of Guiana (*Hymenæa Courbaril*). This tree is common in most parts of tropical S. America, attaining great size and age. From the bark of the stem, and from the roots, there exudes a resin bearing much resemblance to the animi of Africa (see pp. 1640–4). It is usually infested with insects; pale-brown, transparent, brittle, of agreeable odour, whence it is employed in fumigating and perfumery; its sp. gr. is 1·028–1·054, according to one authority, or 1·082, according to another; it is readily melted by heat, insoluble in water, but completely soluble in boiling alcohol. It is capable of application to varnish-making, like copal, and is universally employed in varnishing the native pottery. There is no evidence to show whether the 670 lb. of "*goma algarroba*" exported from Maracaibo (Venezuela) in 1880, and valued at 167½ dol. (of 4*s.* 2*d.*), was this substance or mezquite, which is also sometimes called *algarroba.*

Kauri, Kowrie, Cowdee, or Cawree (Fr., *Dammar austral, de la Nouvelle-Zélande*; Ger., *Kaurie-copal*).—This now familiar resin is afforded by several species of antipodean pines, chiefly *Dammara australis*, and in minor quantity by *D. ovata*, *D. Cookii*, and *D. lanceolata*, of New Caledonia, and *D. Brownii* of Queensland.

D. australis is now to be found growing only in the N.-W. peninsula of the N. island of New Zealand, between 34½° and 37½° S. lat., though the fossil resin is found embedded in the soil and in the coal-seams in various other parts of the colony, even so far south as Stewart's Island, showing that the tree formerly ranged over the whole colony.

The largest quantity of marketable kauri is dug out of the ground. It is found at various depths, from just above the surface of the soil to many feet below. It is found on bare hill-sides, on flat clay lands, in swamps, and even in some places that are covered with a more or less thick coating of volcanic débris. Sometimes the fossil resin is found in small detached lumps, and at other times large deposits occur in one hole. On cultivated land, it is not unfrequently turned up by the plough; and in many places, the cutting of drains in swamps has revealed large quantities. The implements used in digging for the fossil resin consist of a spade and a spear. The spear is a long steel rod, about ½ in. diam., with a wooden handle, like that of a spade or shovel. The rod is brought to a point, and the digger pierces it into the ground on the little knolls that indicate the probable sites of defunct trees. Practice and experience enable him to tell whether he is touching a stone or a piece of the resin. When he touches the latter, he digs around it until it is extricated, and then renews the search as before. The number of persons regularly engaged in digging varies from 1800 to 3000, the greater part of whom are Maoris, but even they do not show any special fondness for the work. They resort to it when they become pressed for food and clothing, on account of the failure of their crops, or other causes. Many Europeans have resorted to this kind of work, but they belong generally to the roughest class.

"Young" or recent resin is also obtained from the living trees, whence, at certain seasons, there exudes a yellowish-white liquid, of viscous consistence and pleasant odour, gradually hardening to an amber-like mass. In the forks of the large branches, deposits varying from a few lb. to nearly 1 cwt. are sometimes met with. When a kauri tree is cut in the bark, even one of the largest and oldest, varying in diameter from 6 to 10–12 ft., it will bleed like a young sapling. In a few weeks, if the weather be dry, a large mass of half-dried resin will have oozed from the wound, not unfrequently appearing in the form of a great thick band, reaching from the wound to the surface of the soil around the tree. When a tree is felled, the stump bleeds in a like manner, until large masses of resin can be broken off from the stump. This "young" resin is white in colour, and has not the rich amber hue which age imparts to it when stored beneath the surface of the soil away from the action of sun and weather.

When the fossil resin is taken out of the ground, it is covered with earth, and its surface is found to be in a partial state of decay. When the digger is tired of work, he puts his resin into a bag, and carries it to his tent or hut, and in the evening, or upon rainy days, he scrapes off the decayed surface until the clear solid gum beneath is reached. When a sufficient quantity of it has been scraped, it is put into a box or bag, and taken to the nearest store or public house, where it is sold for what it will bring. Sometimes the purchaser will assort it, but it is not generally assorted till it reaches the city buyer, who employs a large number of skilled hands for that purpose. The resin, after it is scraped and assorted, is packed carefully in boxes, so as to prevent the lumps from breaking. It is then ready for export. The dust and scrapings are also exported.

The total exports of the resin from New Zealand rose from 2850 tons in 1869 to 5054 in 1871, and fell to 2568 in 1874; in 1880, they were expected to reach 5500. More than $\frac{2}{3}$ goes ultimately to the United States, being either shipped direct to New York and Boston in sailing vessels, or viâ London. Our imports rose from 36,514 cwt. in 1876, to 60,844 cwt. in 1880, from New Zealand alone; in the latter year, there were 2916 cwt. additional from other countries, the total being 63,760 cwt., value 192,658*l.* Some of the resin is used in New Zealand for varnish-making, and some of the "young" resin is consumed as a masticatory by the Maoris. The living forests are rapidly disappearing. The Government has taken no steps for their perpetuation, either by conserving or planting; and at the present rates, it is estimated that 50–80 years will see the bulk of the trees destroyed. The question remains, what amount of the fossil resin may be assumed to exist, but it is extremely difficult to form any correct opinion. Our re-exports of the resin in 1880 were 22,523 cwt., 62,133*l.*, to the United States; 3334 cwt., 11,941*l.*, to Holland; 2842 cwt., 10,227*l.*, to Germany; 2019 cwt., 7835*l.*, to other countries; total, 30,718 cwt., 92,136*l.* The approximate London market values are:—Packings and rough, 20–80*s.* a cwt.; scraped, 46–97*s.*; good to fine scraped, 55–122*s.*; selected, 115–200*s.*

Kauri occurs in commerce in large pieces; the fossil resin is usually pale-yellow or greenish-yellow, dirty-brown in inferior samples. The lustre is sometimes opaline; the fracture is conchoidal and vitreous; the odour is balsamic, and pronounced and characteristic in recently-broken or well-preserved pieces; the flavour is aromatic and pleasant; the sp. gr. of the New Zealand resin is 1·062–1·109, that of the New Caledonian is 1·119. It readily melts and dissolves in boiling alcohol, and in turpentine-oil; also in sulphuric acid, with a red colour. The Maoris burn it to obtain a fine black pigment from the smoke, and use it as a masticatory. In Europe and America, it is chiefly employed for making a varnish rivalling copal, and for giving a gloss to calicoes. Some of the finer specimens are made to replace amber in jewellery, but are less hard and more brittle. It has been used to some extent as a substitute for shellac in photographic varnishes.

Kino (Fr. *Kino*; Ger. *Kino*).—The term "gum kino" is applied to a class of astringent extracts of varied origin, none of which can accurately be called either resins or gums.

1. *E. Indian or Amboyna Kino.*—This is obtained from *Pterocarpus Marsupium*, a common tree in the Central and S. parts of the Indian peninsula, and in Ceylon; and a liquid kind from *P. indicus*, of S. India, Burma, Malacca, Penang, the Andamans, and Malaysia. The collection of the juice is effected in the following manner. A perpendicular incision, with lateral offshoots, is made in the stem of the tree when blossoming has set in, and a receptacle is placed at the foot of the incision. The exuding juice appears like red-currant jelly, but it soon thickens by exposure to the air, and when sufficiently dried, is packed into wooden boxes for exportation. It is one of the reserved timber-trees of the Government forests in Madras, and its juice is collected by natives, who pay a small fee for the permission. The hardened juice consists of blackish-red,

angular, pea-like grains, partially soluble in water, almost entirely in spirit of wine of sp. gr. 0·838, readily in caustic alkaline solutions, and largely in a saturated solution of sugar. The liquid kino produces a very inferior article on drying. The annual collection of kino in Madras probably does not exceed 1–2 tons. Its approximate London market value is 60–150*s.* a cwt. It is employed medicinally (see p. 815), and in the manufacture of wines, and might be employed as a source of tannin in dyeing and tanning, if sufficiently cheap.

2. *Butea, Bengal, Palas or Dhak Kino.*—This variety is afforded by the *palas* or *dhak* tree (*Butea frondosa*), common throughout India and Burma, and affording a dyestuff (see p. 867, Tisso), and a fibre (see p. 933), as well as by *B. superba* and *B. parviflora.* During the hot season, there issues from natural fissures and from wounds made in the bark of the stem, a red juice, which quickly hardens to a ruby-coloured, brittle, astringent mass. It occurs in small drops or tears, and in flat pieces which have been dried on leaves, and is almost always mixed with bark-fragments. It is transparent, freely soluble in cold water, and does not soften in the mouth. It is unknown in European commerce, but is employed in India as a substitute for the kind first described.

3. *African or Gambia Kino.*—This is derived from *Pterocarpus erinaceus*, a native of Tropical W. Africa, from Senegambia to Angola. The juice exudes naturally from fissures in the bark, but more abundantly from incisions, and soon coagulates to a blood-red and very brittle mass, known to the Portuguese of Angola as *sangue del drago* ("dragon's-blood"). It is practically undistinguishable from the officinal kind first described, but is not a regular article of commerce.

4. *Australian, Botany Bay, or Eucalyptus Kino.*—Several species of *Eucalyptus* afford astringent extracts, those from the "red," "white," or "flooded" gum (*E. rostrata*), the "blood-wood" (*E. corymbosa*), and *E. citriodora,* being quite suitable for replacing the officinal kind. It is chiefly obtained by woodcutters, being found in a viscid state in flattened cavities in the wood, and soon becoming inspissated, hard, and brittle. Minor quantities are procured in a liquid state by incising the bark of living trees, forming a treacly fluid yielding 35 per cent. of solid kino on evaporation. It is imported from Australia, but there are no statistics to show in what quantity.

Kos.—This name is applied in Ceylon to a yellow, viscid, milky juice obtained from the jack tree (*Artocarpus integrifolia*). While some accounts describe it as furnishing bird-lime, and therefore somewhat resembling guttapercha, others compare it with the babul variety of gum arabic (see p. 1632).

Wiesner describes a resin, which he calls "dammar selo," as a product of this species in Singapore. It occurs in fragments and masses, often containing woody refuse. Freshly-fractured pieces are sulphur-yellow. The sp. gr. is 1·099; the melting-point, 132° (269½° F.).

Lac, Gum Lac, Shellac, Stick Lac (Fr., *Laque*; Ger., *Lack*).—Lac is a resinous incrustation formed on the bark of the twigs and branches of various trees (all, it is believed, yielding more or less of a gummy, resinous, or saponaceous fluid) by the "lac-insect" (*Coccus Lacca*). The incrustation is cellular, deep-red or orange-coloured, semitransparent, hard, and breaking with a crystalline fracture. The substance is mainly formed by the female insects, which generally far outnumber the males. Each female inhabits a cell, and the incrustation seems intended to serve as a protection for her progeny. As soon as she is completely covered by the secretion, the female lays her eggs, and dies. The young, when hatched, work their way out through the body of the mother, eating the red substance with which her body is filled, and thus assuming the hue which gives them their value in dyeing. Having pierced the resinous incrustation, the young swarm on to the bark, and at once commence secreting lac. The insect never wanders from the branch to which it first attaches itself, and this, after affording nourishment to millions of the insect, decays; but the extinction of the species, which thus seems inevitable, is remedied by the frequency and distance to which the insect is transported by other insects and by birds. Artificial propagation is also now well understood, and described further on (see p. 1669).

The Indian trees frequented by lac, or on which it will attach itself, are very numerous. The following list is probably far from being exhaustive:—*Acacia arabica* and *A. catechu*, *Aleurites* [*Croton*] *lacciferum*, *Anona squamosa*, *Butea frondosa* and *B. superba*, *Carissa spinarum*, *Celtis Roxburghii*, *Ceratonia siliqua*, *Croton Draco* and *C. sanguiferum*, *Dalbergia paniculata* and *D. latifolia*, *Eriolæna Hookeriana*, *Erythrina indica* and *E. monosperma*, *Feronia elephantum*, *Ficus cordifolia*, *F. elastica*, *F. glomerata*, *F. indica*, *F. infectoria*, *F. religiosa*, *F. venosa*, and *F. villosa*, *Garruga pinnata*, *Gordonia floribunda*, *Inga dulcis*, *Kydia calycina*, *Lagerstrœmia parviflora*, *Mangifera indica*, *Mimosa cinerea*, *Nephelium Litchi*, *Ougeinia dalbergioides*, *Prosopis spicigera*, *Pterocarpus Marsupium*, *Schleichera trijuga*, *Shorea laccifera* and *S. robusta*, *Spathodea Rheedii*, *Tectona grandis*, *Terminalia tomentosa*, *Vatica laccifera*, *Vismia laccifera* and *V. micrantha*, *Zizyphus jujuba* and *Z. Xylopyrus.* The quantity and quality of the resinous secretion vary considerably according to the tree on which it is found. The best is confined to three trees, the *palas* or *dhak* (*Butea frondosa*), the *peepul* (*Ficus religiosa*), and the *koosum* (*Schleichera trijuga*). The last-mentioned tree is said to produce two crops annually (April–June, and October–December) in the Central Provinces of India, and its lac is reported to keep good for 10 years, while that of the others lasts 2 years only.

In India, lac occurs in Bengal and Assam (abundantly), the N.-W. Provinces and Oudh (sparingly), the Central Provinces (abundantly), the Punjab, Bombay, Sind, and Madras (more or less sparingly), and Burma (abundantly in some places). Lac is also found in some other countries of S. Asia,—Siam, Ceylon, some of the islands of the E. Archipelago, China,—Siamese lac being held in high estimation. In India, the best lac is obtained from Assam and Burma. The quantities produced and utilized vary greatly in different provinces, according to circumstances, certain forests being rich in lac, which has hardly been touched, owing to difficulty of access, and cost of carriage to the place of manufacture and port of shipment. In Bengal, lac is produced abundantly in the jungle tracts of Beerbhoom, Chota Nagpore, and Orissa. In various places in the forests of Assam, it is also found in large quantities, and forms a regular article of trade, a portion of the production being manufactured at Dacca, and the rest sent to Calcutta.

The lowest average yearly supply from the Pooroolia district in Chota Nagpore is 15,000 *maunds*, the actual yield being considerably more, and capable of great extension. From Singhboom, in 1867, about 1250 *maunds* of lac were exported. In the Gya district, the supply is estimated at 12,000 *maunds*; in Kamroop (Assam), about 5000 *maunds*, with great capacity for development; in Hazaribaugh, 2000 *maunds*. These figures probably do not by any means approximate to the actual yield of the districts named. In Bengal, lac is gathered twice a year—from mid-October to the end of January, and from mid-May to mid-July. In the N.-W. Provinces, lac is obtained in some quantities from the Garhwal forests; and, some years ago, was largely exported to the plains. It is probable that most of the lac now brought down from Garhwal is consumed in the local manufacture of toys and ornaments, and that very little, if any, is for exportation from Calcutta. In the Punjab, the production of lac is universal, but it is much inferior in quality to the lac of Central India or Bengal. In Sind, lac is only found in the forests about Hyderabad, 12 miles north and south, but in these abundantly. In the other forests of the province, it either does not exist at all, or in such small quantities that its collection does not pay. The cause of its occurrence near Hyderabad is worthy of investigation. It is found on the babool (*Acacia arabica*), and is gathered from October till April–May. This tree seems while in full vigour to be exempt from the attacks of the insect; it is chiefly infested when in the semi-dry state, and is not unfrequently killed outright. The lac produced in Sind is largely used in the manufacture of the well-known lacquered ware of Hyderabad. In Oudh, lac is gathered in the more wooded parts of the S.-E. districts (Roy Bareilly and Partabgurh) from various species of *Ficus*, especially *F. religiosa*. It is exported to the Mirzapore factories and elsewhere. Large supplies might also be procurable from the N. forests, but the collection might be unprofitable, owing to the want of manufactories within a reasonable distance. Government obtains half the produce in quantity or value from the gatherers. All the districts of the Central Provinces produce lac, but it is particularly abundant in the E. parts. Large quantities are consumed in the towns in the manufacture of bracelets and other articles, but most districts also export it to a greater or less extent. These provinces could readily supply 25,000 tons of stick-lac annually. Most of the lac produced in the Jubbulpore district is consumed in a European factory in the town. It also comes to Jubbulpore and Mirzapore in large quantities from Raipore, Bilaspore, Saugor, and Mundla. In Mundla, the right of collecting lac from the Government jungles has been leased to the owners of the Jubbulpore factory. In Sumbulpore, a Mirzapore firm (European) has for a long time practically held the monopoly of lac collection. Boorhanpore and Bombay receive supplies, though in small quantities, from the Nerbudda and Nagpore divisions. In the Hoshungabad district of the Central Provinces, the chief mart for lac is at Sobhapore, others of importance being Hoshungabad and Babai. Into Sobhapore, lac is imported largely from Bankheri, Futtehpore, and some of the hills on the other side of the Nerbudda, and from some of the jungles of the Nursinghpore district. Hoshungabad and Babai receive lac from the malgoozaree jungles and the hills beyond the Nerbudda, while it comes to Hurda and Seonee from the jungles of the Hoshungabad and Betul districts. The lac-collectors are mostly jungle tribes, who sell the produce in small quantities to Patwas, who again sell it in larger quantities to the regular dealers.

Much has been done in the Central Provinces of India in the way of propagating or cultivating lac. In forming preserves for this purpose, the first point to be considered is the species of tree which it will be desirable to utilize for the nurseries. The choice should fall (first) upon that or those found in greatest plenty, assuming they are adapted to the purpose, and (second) upon that which yields the best product. Of the trees previously named, the light-golden resin obtained from the *koosum* is the finest, as from it the most valuable orange shellac is manufactured; next in quality is that obtained from the *palas*, which yields the garnet lac of commerce. Wherever possible, therefore, the *koosum* tree should be chosen for standards; but as the *palas* is generally found in much greater numbers, area for area, its produce will nearly compensate in quantity for the reduction in its value.

Having selected the forest for experiment, the next point to fix on is the local date on which the insects leave the parent cells, a step of great importance, and one on which the first success of the plantation will very greatly depend; as, should the work of gathering brood lac be delayed until visible proof of the exit of larvæ is obtained, a vast quantity will be killed in the operations of collection, transport, and tying the encrusted twigs on the standards selected for the nurseries. The date of evolution having been fixed on with some certainty, twigs of that season's lac should be gathered about 15 days before, wrapped up in a few straws of grass, and attached to the trees selected for production, with threads of *palas* root fibre, or something else as easily obtained; each twig should be 9–12 in. in length, and be attached to the upper and middle branches of the tree. The grass tied round the twigs acts as a means of communication from the lac to the branches and leaf petioles, by which, many insects are saved that would otherwise die from want of nourishment, for, owing to the crookedness and irregularities of the incrustations, contact between them and the branches is seldom complete. It is also of importance to tie the brood lac to the upper and middle branches, as many of the lower ones, by this arrangement, become covered with insects, which are shaken or fall from above; whereas, if the lac be attached to the lower portion of the tree, many larvæ must fall to the ground and be lost. When attaching the twigs, it appears necessary to take care that the wood of the standard is not of denser composition than the wood of the tree from which the brood lac is gathered, as it is believed that the larvæ reared on soft-wooded trees are comparatively weaker than those which are found on species of harder texture. The brood lac yielded by the *koosum*, a very hard-wooded tree, appears best suited for propagating purposes, as it succeeds on trees of all other species. When several trees of the selected species grow together, it does not appear necessary at first to artificially cultivate more than ¾ of them, as, during the succeeding evolution, the remaining ¼ will almost certainly be brought under preparation by natural means; but as the success of the crop depends principally on the supply of juices obtained by the female insects during the period they continue to deposit the resin, it is necessary to place the brood lac on the youngest and most sappy branches.

Of the points to be noted in making preserves, the one of greatest importance, perhaps, is the fact that the lac incrustations may be plucked several days before the larvæ appear,—a knowledge of which will enable a larger number of trees to be prepared during one working season than if it was necessary to delay the operations until the evolution actually took place, as, owing to this latter being nearly simultaneous in and about one locality, the period for forming the plantation would be necessarily limited to the number of days it took for the cells to become empty; besides which, by attaching the lac twigs before the birth of the larvæ, great numbers are saved, which would otherwise perish during the process of being attached to the trees. Experiment has proved that the incrustations may be gathered 2–3 weeks before the exit of the young, by which, as before explained, much better results will be obtained than if it was necessary to delay the work until this event took place. The date of exit varies considerably in forests separated by comparatively short distances. These differences arise less from the latitudes of the forests than from certain local conditions. There is much reported variation in the number of evolutions, and consequently in the number of crops which are obtained, in different countries. In Mysore and Burma, it would appear that three evolutions take place during the year. In the Central Provinces, only one good crop in a year can be hoped for.

After the larvæ appear, they crawl about the stems of the plant in search of young juicy spots, from which, when once fixed by their probosces, they cannot be removed without fatal injury. The male and female are identical in size and shape, and both commence at once the formation of their cocoons by excreting a substance resembling lac, those of the males being ovoid or elliptic in form, while those of the females are more circular, and exhibit three distinct apertures arranged in triangular fashion in their roofs,—one being the anal aperture through which impregnation is accomplished, and the larvæ eventually swarm; the other two, those by means of which the insect obtains a supply of air. About ten weeks after birth, an important change has taken place in the larvæ; the female cocoons are completed, and the insects have assumed the final or imago state; as the female remains fixed in the position she first took up on the twig, the male is obliged to seek her, which he does by leaving his cell in a backward manner to the ventral aperture, and crawling on to the female cells, where he fulfils his office, and almost immediately after dies. This exit of male insects is a fact well to know, as, owing to the smallness of the animal and his superficial similarity to the original larva form, it is possible for a novice to mistake such an evolution for one of young larvæ, and to commence gathering the twigs under the impression that a new birth of the latter had taken place. If the lac is plucked before or immediately after impregnation has been accomplished, the females must perish from being cut off from their sap supplies, and, as a natural consequence, the young brood must be destroyed with them. Impregnation having been accomplished, the female busies herself in sucking up large quantities of vegetable juices, increases greatly in size, and begins the excretion of the true lac. The females must be attached to young twigs by which bountiful supplies of fluid will be supplied them, otherwise they will die, or never become fully developed, the lac cells will be small in consequence, and the eggs will suffer in number and condition. This no doubt is the reason why, in districts where the seasons are dry, and where showers are of unfrequent occurrence during the hot weather, the summer crop is invariably poor and scarcely worth collecting. Moisture is one of the great essentials for a fine crop of lac, and many disappointments result from fixing on dry arid spots for the formation of the plantations. The females cannot obtain sufficient nourishment at this period from the sapless stems, and their death will be recognized by the pitted appearance assumed by the cells, the crowns of which fall in as the insect contracts within them, and by the cessation of the growth or disappearance of the white filaments which obtrude from the spiracular orifices. Species such as *koosum* and *gooler* (*Ficus glomerata*), which most frequently are found growing along the banks of rivers, where the atmosphere is humid, are, for these reasons, especially adapted for yielding good crops of lac; while the *palas* offers advantages, as its sap-producing functions are actively employed during the hottest season of the year, when it forms both new wood and leaves.

Besides the damage brought about by fires, drought, and frost, which to some extent can be guarded against, there are other enemies to the crop which are still more difficult to contend with. Ants, both large and small, attend the female cells for the purpose of licking up the sweet excrement; they appear to hurt the insect by biting off the ends of the white filaments, and thus bringing many an occupant of the cells to a premature end by stopping the supplies of breathing-air, which the filaments serve to convey through the holes in the lac. Where ants are seen about the lac, it never appears healthy, and many cells are found with the insect dead inside them. The lac whilst on the tree is also attacked by the larva of a moth, which appears to be a species of *Galleria*. It eats the juicy females of the coccus, and bores through the lac cells; it is found both in the field and the store-room. A second species appears to belong to the genus *Tinea*. These insects destroy the colouring matter contained in the females, and also all hope of a brood of young from the cells visited by them. At present there seems to be no way of protecting the lac from their depredations. The ants, however, may be circumvented in two ways,—either by surrounding the trees with wood ashes, or with something sufficiently attractive to draw their attention away from the incrustations.

It seems possible, owing to the great drain made on the sap of the young branches by the insects, that considerable damage will be found to result to the trees on which they are propagated, and that it will be necessary at some future time to fix a limit to the continuous cultivation of lac on the same tree; at any rate, it will probably be found beneficial to both lac and tree if a regular system of pruning be carried out, to encourage the formation of young twig or branch wood.

In Mysore, lac is produced in all three divisions, but chiefly in Nundidroog, and is found most commonly on *Vatica laccifera*. The insect thrives well in Mysore, and it might by cultivation be raised to any extent on trees growing on barren soil which would otherwise yield no return. The carob tree (*Ceratonia siliqua*), which is about to be introduced into Mysore, will probably, if it will succeed in the province, be found well adapted to this purpose. It will flourish in dry and stony soil, and the lac insect seems to be much attached to it. The supply of lac in the province is large, and could no doubt be considerably increased. Apparently the lac produced in Madras and Mysore is consumed locally, for the exports from Madras are next to nothing.

The mode of propagation in Mysore is as follows:—The insects are applied to the branches of the trees (*Vatica laccifera*) 3 times in the year, the old branches with the insects on them being lopped off, made into small bundles, and tied up to fresh branches. The insects then begin to build their cells on the branches, and continue occupied for about 3 months. When this period has expired, the young leave their abode. This opportunity is carefully watched, the insects are secured for further use, and the lac-covered branches are gathered, each tree producing on an average 2½ *seers*. The insects are invariably applied to immature trees or saplings, as the old trees do not contain sufficient sap for their nourishment. It is as much artificially propagated, or cultivated, as any other raw material for manufacturing purposes. If it takes to a tree not considered suitable for elaborating the colouring matter and gum, it is removed thence, and placed upon others where it thrives better. In Central India, the application of "seed" to a new tree takes place in June for the November crop, and in October for the April crop. If the seed is placed on a congenial tree, the produce does not deteriorate from the same seed being left any time on the same tree, so long as the tree retains its vigour. It has been successfully propagated after a transport of some hundreds of miles.

The vast forests of British Burma are capable of producing an almost unlimited quantity of lac; but hitherto the largest portion of the quantity available for shipment has been brought from Upper Burma and the Shan States, and the principal market is found in Calcutta, where the rough stick-lac is manufactured into shell-lac for export. The product is, to a small extent, procurable in the hill tracts of Arakan, and with encouragement it is susceptible of development. Prizes have been offered to the people to stimulate the propagation of the insect, and State plantations have been formed at Toungoo, and Magayee, with success, while another at Sittang has quite failed.

The Padoung Karens, beyond the N.-E. frontier of Burma, carry on the production of lac upon a large scale, and in a systematic manner. In Assam, a small quantity of lac is produced in the district of Darrang. In some districts, the insect is artificially reared on the *jhuri* tree (*Ficus cordifolia*).

In its raw condition, incrusted around the twigs of the tree on which the insect feeds, lac is technically called "stick-lac." The twigs are generally, for convenience of transport, cut up in lengths of 2–3 in., and it is probable that a great deal of material is wasted in this process. The objects of the manufacturer are:—(1) To separate the resinous incrustation from the wood; (2) to free the resin from the colouring matter; (3) to convert the resin into what is known as "shell-lac"; (4) to form from the colouring matter cakes of dye known as "lac-dye." As generally practised, these processes are conducted in a primitive manner. The first step is to strip the twigs of their covering of lac, for which purpose, they are placed under a roller on a platform; the roller being rapidly passed over them, the coating comes off, leaving only a small portion adhering, which requires hand-picking for its separation. The wood is rejected. The separated lac is reduced by rolling or other simple means till it will pass through a moderately coarse sieve, say ¼-in. meshes. It is next placed in large tubs half-full of water, and is washed by coolies, who, standing in the tubs, and holding on to a bar above by their hands, stamp and pivot about on the heels and toes, until, after a succession of changes, the resulting liquor comes off clear. The lac (now "seed-lac"), having been dried, is placed in long cylindrical bags of cotton cloth of medium texture, and about 10 ft. long and 2 in. diam. These bags, when filled, are taken to an apartment where there are a number of *chulas*, or open charcoal furnaces. An operator grasps one end of the bag in his left hand, and slowly revolves it in front of the fire; at the same time an assistant, seated at the other end of the bag, twists it in the opposite direction. The roasting soon melts the lac in the bag, and the twisting causes it to exude, and drop into troughs placed below, which are often only the leaves of *Agave americana*. When a sufficient quantity in a molten condition is ready in the trough, the operator takes it up in a wooden spoon, and places it on a cylinder, some 8–10 in. diam.; sometimes the cylinder is of wood, the upper half being covered with brass; in some places, the freshly-cut, smooth, cylindrical stem of the plantain is used for this purpose; or the cylinder may be of porcelain, filled with some heat-absorbing material. The stand which supports the cylinder gives it a sloping direction away from the operator. Another assistant, generally a woman, now steps forward with a strip of *Agave* in her hands, and with a rapid and dexterous draw of this, the lac is spread at once into a sheet of uniform thickness, which covers the upper portion of the cylinder. The operator cuts off the upper edge with a pair of scissors, and the sheet is lifted up by the assistant, who waves it about for a moment or two in the air, till it becomes quite crisp. It is then held up to the light, and any impurities (technically "grit") are simply punched out of the brittle sheet by the finger. The sheets are laid one upon another, and, at the end of the day, the tale is taken, and the chief operator is paid accordingly, the assistants receiving fixed wages. The sheets are placed in packing-cases, and, when subjected to pressure, break into numerous fragments. In the fresh state, the finest quality has a rich golden lustre. These sheets and fragments form the "shell-lac" or "shellac" of commerce.

"Button-lac" differs from shellac only in form. Instead of being drawn over a cylinder, the melted lac is allowed to fall upon a plane, and assumes the shape of large, flat, gingerbread-nuts, about 3 in. diam. and ⅙ in. thick. The manufacture of lac-dye is described on pp. 861–2.

Elliott Angelo, of Cossipore, has adopted improved methods and machinery in his factory. The first of these is in the washing department, where steam-driven cylinders with internal rotating arms are used. The macerated seed-lac is melted in closed steam-heated vessels, with addition of rosin, which is said to act as a flux and a preventive of burning, and subsequently to evaporate. The cylinders for making shellac are formed of zinc, and maintained at an equable temperature by internal pipes supplied with tepid water. Lac is frequently adulterated with orpiment, which imparts a fine yellow colour; and very largely (up to 50–60 per cent.) with common rosin. The latter may be readily detected by its odour on breaking the mass. The chief grades are "fine orange D C," "liver," "garnet," "native leaf," and "button." The approximate relative market values in London are:—Orange, 65–200*s.* a cwt.; liver and native orange, 65–175*s.*; garnet, 60–155*s.*; button, dark to middling, 60–180*s.*; button, good to fine, 70–200*s.*; seed-lac, 80–90*s.*; stick-lac, Siam, 45–140*s.* In India, lac is used chiefly in the manufacture of various trinkets. In Europe, it is largely employed in the preparation of spirit-varnishes, cements, lithographic ink, and sealing-wax, and as a stiffening for hats. White shellac is usually kept in water, by which means, its capability for solution is preserved. This property is lost within a fortnight of its preparation, by exposure to the air; within the period, it is readily soluble in naphtha or "finish."

The trade in lac is extensive. Our imports of seed, shell, stick, and dye lac have been:—98,855 cwt., 530,017*l.*, in 1876; 100,442 cwt., 395,831*l.*, in 1877; 79,593 cwt., 273,923*l.*, in 1878; 51,159 cwt., 179,305*l.*, in 1879; 58,081 cwt., 369,317*l.*, in 1880. The imports of 1880 were contributed as follows:—Bengal and Burma, 54,179 cwt., 347,998*l.*; other countries, 3902 cwt., 21,319*l.*; total, 58,081 cwt., 369,317*l.* Our imports from Bengal and Burma fell from 95,058 cwt., in 1877, to 47,368 cwt. in 1879, and only recovered to 54,179 cwt. in

1880. Our imports from the Straits Settlements fell from 5228 cwt. in 1876, to 541 cwt. in 1879, and only recovered to 832 cwt. in 1880. Our re-exports in 1880 were:—To the United States, 14,389 cwt., 70,223*l.*; Germany, 10,458 cwt., 61,542*l.*; Holland, 4200 cwt., 23,336*l.*; Russia, 2801 cwt., 16,319*l.*; France, 2653 cwt., 17,946*l.*; other countries, 4124 cwt., 21,984*l.*; total, 38,625 cwt., 211,360*l.* It is necessary to repeat that all these figures include lac dye. The Indian exports, excluding lac dye, were:—68,264 cwt. in 1875, 92,915 in 1876, 109,661 in 1877, 95,075 in 1878, 83,162 in 1879. The relative proportions of the several kinds in 1875–6 were:—Shellac, 80,645 cwt.; stick-lac, 207 cwt.

There remains to mention under this head the discovery of the same or a very closely allied insect, capable of affording the same product, in some portions of the United States. The plants on which the insect has been found are *Acacia Greggii*, and the creasote bush, stinkweed, or etiontio (*Larrea mexicana*). These plants flourish abundantly from S. Utah to New Mexico, and from the Colorado Desert to W. Texas, wherever the rainfall amounts to 3 in. annually. The second species is particularly common on the hills bordering the Gila, and on the sandy wastes adjacent to Tucson and Camp Lowell, in Arizona. With care and cultivation, there seems to be no reason why these natural resources should not be developed so as to render America independent of foreign supplies of shellac.

Lignum aloes.—See Perfumes—Agar, pp. 1523–4.

Liquidambar.—See Storax, pp. 1682–3.

Mahogany.—The mahogany tree, *Swietenia Mahogani* (see Timber), under cultivation in Bombay, affords an abundance of a superior silvery-looking gum, of which no use seems to be made.

Mango.—On wounding the bark of the mango (*Mangifera indica*), which is common everywhere in India, there exudes a soft, reddish-brown gum-resin, hardening by age, and much resembling bdellium. It is often mottled in such a way as to lead to its confusion with asafœtida (the *hing* variety), or with amygdaloid benzoin. It has a strong and persistent odour of ripe mangoes, and emits a smell of roasting cashew-nuts when burnt in a candle-flame. It dissolves partially in water, and completely in spirit. It is used medicinally by the natives of India.

Mastic or Mastich (Fr., *Mastic*; Ger., *Mastix*).—The lentisc or mastic shrub (*Pistacia Lentiscus*) is a native of the Mediterranean coast region, including Spain, Portugal, Italy, Greece, the islands on the Turkish coast, Syria, Morocco, and the Canaries. Formerly the resinous exudation was collected from the plant in Cyprus, and experiment has proved that it might easily be obtained in some of the other members of the Archipelago, yet the production is now exclusively confined to the island of Scio (Chios). The mastic country of Chios is usually flat and stony, with little hills intervening, and few streams. The principal villages engaged in the industry are Calimassia, St. Georges (S. of Anabato), Nénita, Mesta, and Kalamoti, besides about a dozen of minor importance. The shrubs are about the height of a man. The bark of the stems and branches contains resin-ducts, which require but slight incision to provoke exudation. About June–August, the bark of the stems and chief branches is thickly scored with vertical cuts, the operation being renewed 3–4 times during the period. The exudation flows freely, hardens, and dries, so that about 15–20 days later it can be collected in little baskets lined with white paper or clean cotton wool. The ground beneath the shrubs is kept hard and clean, so that accidental droppings may not be spoiled. The small quantity spontaneously exuded by the lesser branches is of superlative quantity. A fine tree may yield a total of 8–10 lb., but a shower of rain during the harvest produces disastrous results; frosts are very injurious to the trees, but of rare occurrence. There are 4 qualities of mastic:—(1) "Cake" is composed of large pieces, and is considered the best by connoisseurs; it is sold chiefly for use in the seraglios, all Turkish women chewing mastic; its price is 120–130 *piastres* (of 2*d.*) per *oke* (of 2·83 lb.), and even more. (2) Large tears are ordinarily worth 90–100 *piastres*. (3) Small tears or pearls fetch 70–85 *piastres*, and are used industrially. (4) Mastic mixed with fragments of leaves and with sand is consumed in the manufacture of the Turkish liqueur called *raki* or "mastic brandy."

Mastic tears are pale-yellow or slightly greenish, the colour deepening with age; they are either dusty and opaque, or washed and glassy externally and transparent internally. They are brittle, with conchoidal fracture, and a turpentinous balsamic odour, and are readily distinguishable from sandarach by softening and kneading in the mouth. The sp. gr. is 1·04–1·07; the softening-point is 80°–99° (176°–210° F.), the melting-point, 105°–120° (221°–248° F.). The resin dissolves in half its weight of pure warm acetone, and slowly in 5 parts clove-oil. The medicinal use of mastic in Europe is a thing of the past, and the little that arrives here is employed in varnish-making. All the good qualities are consumed in the Levant. Chios exported 28,000 lb. "picked" and 42,000 lb. "common" mastic in 1871. The approximate London market value is 2*s.* 6*d.*–4*s.* 6*d.* a lb.

In the Indian bazars, another mastic is met with, which is afforded by *Pistacia cabulica* and *P. Khinjuk*, trees found growing all over Sind, Beluchistan, and Afghanistan. The better qualities much resemble Chian mastic—being sold as *mustagi-rúmí* ("Roman mastic") in India—and sometimes appear in the European markets as "E. Indian" or "Bombay" mastic.

The Arab tribes of N. Africa collect the resin of *P. atlantica* (see Turpentine—Chian, p. 1687), and use it as mastic.

The term "Cape mastic" has been applied to the resinous exudation of the resin-bush or *harpuis-bosch* (*Euryops multifidus*), growing plentifully at the Cape, notably in the Clanwilliam district, and utilized by the colonists.

The product exported from Manilla as "gum mastic" is probably dammar (see p. 1644).

Mezquite, Mesquit, or Mosqueit.—The mezquite tree (*Prosopis glandulosa*) is a native of the W. States of America, ranging from the Canada river southwards into Mexico, appearing in Texas, not far from the coast, and constituting the most abundant tree as far west as Colorado and the Gulf of California. It frequents dry and elevated situations where scarcely anything else will grow. Other species are named *P. dulcis* and *P. juliflora*. From natural fissures in the bark of the stem and branches, there spontaneously exudes a gum which can hardly be distinguished from *Acacia* gums (see Arabic, pp. 1630–3, especially Senegal), and is quite suitable for replacing them. As it exudes, it concretes into tears and lumps of various sizes, ranging in colour from pale-yellow to dark-amber. It is very brittle and pulverulent, and has a brilliant fracture. The quantity yielded by one tree is 1 oz.–3 lb., the best being from the branches; it might probably be much increased by judicious incising. As much as 12,000 lb. of the gum has been gathered in one year in Bexar county, Texas, and a like quantity between that and the coast. It is sent to San Francisco from the Mexican ports of the Pacific, and has recently been exported. The commercial value of the finest Mexican gum is about 1*s.* a lb.

Mochurrus, Mucherus, Mojrus, or Mochras.—This is an astringent, gummy exudation, forming irregular, inflated, hollow, dark-brown excrescences on the *Salmalia malabarica*, and apparently a result of a diseased action, whose origin has not yet been investigated. It is used medicinally by the natives of S. and W. India, mainly for its astringent qualities.

Moringa.—Moringa gum is afforded by *Moringa pterygosperma* (see Ben-oil, pp. 1378–9), and has sometimes been confounded with mochurrus. The samples vary in colour from red and pink to almost white; and in shape, from stalactitic pieces to tears. It is insoluble in water. It is obtained in great quantity, and has been proposed as a substitute for tragacanth, but its colour would probably be an obstacle. About 8·3 per cent. of the natural gum is soluble in alcohol, and 7·85 of the remainder in ether, while the residue is almost completely dissolved by alkalies.

Myrrh (Fr., *Myrrhe*; Ger., *Myrrhe*).—The sources of myrrh have been a puzzle to generations of pharmacologists, and though the recent labours of Wykeham Perry, Capt. Hunter, and Dr. Trimen have helped to remove some of the doubt surrounding the subject, there is still abundant scope for further research. That myrrh is afforded by one or more species of *Balsamodendron* seems certain. The greater part, the myrrh proper ("African" or "Turkey" myrrh), called *môr* by the Arabs, *mulmul* by the Somal, and *hira-bôl* in India, is ascribed to *B. Myrrha*, the *didthin* of the Somal, which Trimen thinks may prove to be identical with the Indian *B. Berryi*. But there is a second kind of myrrh, holding an intermediate position between true myrrh and the bdelliums, once known as "E. Indian myrrh," the *bissa-bôl* of Indian commerce, and *habaghadi* of the Somal and Arabs; this has been referred by Holmes to *B. Kafal*. A third variety of myrrh, called "Arabian" by Hanbury, is obtained in the country lying E. of Aden, from a plant which differs considerably from *B. Myrrha*, and which the Kew authorities are inclined to consider as *B. Opobalsamum*, and identical with Berg's *B. Ehrenbergianum*.

The geographical distribution of myrrh-yielding plants is, of course, similarly indefinite. Four distinct districts may be named as the probable sources:—(1) Somali-land, extending southwards from Cape Gardafui and Berbera; (2) the triangle included between Tajura, Harrar, and Shoa; (3) the neighbourhood of Ghizan, on the Arabian shore of the Red Sea, opposite Masowa; (4) the Arabian coast country stretching E. of Aden. The variety of the gum-resin yielded by each locality is not a matter of certainty. It is generally supposed, however, that true myrrh (*hira-bôl*) is obtained from the first-named district, and brought from the Wady Nogal, Mareyan, Ogadain, and Agahora, many trees being found also on the hot sunny declivities of the coast range called Ahl or Serrat mountains, at 1500–3000 ft., and a few on the hills behind Bunder Mareyeh. The *bissa-bôl* variety would seem to be chiefly the product of Harrar and the country lying W. of it, notably the district S.-W. of Zeila, the Adal desert, and the jungle of the Hawash. The Ghizan plant has been called *B. Ehrenbergianum*, and identified by Oliver with *B. Opobalsamum*, a myrrh-yielding plant found by Schweinfurth on the Bisharrin mountains of Abyssinia, but Schweinfurth does not admit the identity. The "Arabian" myrrh is produced in the Fadthli country, some 40–60 miles E. of Aden. The article locally known as *hotai* or *hodthai*, derived from *B. Playfairii*, is a bdellium rather than a myrrh, and has been described under the former name (see p. 1637). It must be admitted that future research may prove the varieties of myrrh to be due to differences in soil, climate, and time and mode of collection, as much as to specific dissimilarity in the plants themselves.

The secretion of the gum-resin, according to Marchand's examination of *B. Myrrha*, is mainly in the cortical layers, with a little in the medulla. Exudation takes place spontaneously, incisions never being made in the plants, though bruising with stones is sometimes resorted to, according to Johnston. It escapes from the bark after the manner of cherry-gum, having at first an oily and then a buttery consistence, and changing its colour while hardening from yellowish-white to golden and finally reddish. It is brought into commerce chiefly by way of Berbera, an E. African port nearly opposite Aden, where it is bought by Banian traders at the great annual fair in November–January, and shipped largely to Bombay. The crude article thus exported, having been collected by ignorant and careless natives, contains all qualities of myrrh, mixed with bdelliums and other foreign resins and gums, and various impurities such as bark and stones. At Bombay, a certain amount of sorting is done, the best samples coming to Europe, the commoner going to China for burning as incense; this sorting is carelessly performed, and needs to be supplemented by a second one here. The article is first sifted to remove the small fragments, and is then hand-picked, yet the greatest care cannot prevent the occasional presence of spurious gums, even in the best grade.

Myrrh may be distinguished from its impurities by its fracture, odour, and flavour. Commercial myrrh (*hira-bôl*) may be conveniently divided into "soft" and "dry," though brokers do not recognize any such distinction. The soft kind occurs in irregularly roundish masses, varying in size from small grains to pieces as large as hens' eggs; it has a dull, waxy fracture, and is readily impressed by the finger-nail, emitting an oily exudation. The fracture often shows whitish markings, either in narrow curves concentric to the side which was attached to the tree, or broad streaks, but never exhibiting cracks filled with transparent resin, characteristic of *bissa-bôl*. The fragrant odour of myrrh is quite *sui generis*; the flavour is similar, aromatic and slightly bitter; the colour varies from deep reddish-brown to almost colourless, the palest being most esteemed. Tiny transparent tears sometimes appear on the usually powdery surface; they are due to the resinification of oil which has been exuded. Soft myrrh, beaten in a mortar for some time, forms a greasy paste, and cannot be powdered. Dry myrrh exists in irregular lumps; its fracture is conchoidal and shiny, resisting the finger-nail, and giving no oily exudation; in odour and flavour, it agrees precisely with soft myrrh; the white markings of the latter are absent. It contains a much larger proportion of gum (75 per cent.). It is possible that the same tree may afford both soft and dry myrrh at different seasons. Parker has shown that the one is not converted into the other by long exposure to the air. In external appearance, *bissa-bôl* is much like soft myrrh; the fracture is waxy, yielding to the finger-nail, and exuding an oily matter; but the whitish markings are traversed by angular interstices filled with transparent reddish-brown resin or gum-resin; and its powerful aromatic odour is quite unlike that of true myrrh, and has been compared with the odour of apples and of "lemon-lollipop," and with the flavour of the spring mushroom. It is possible that this is the *addi* or "false myrrh" of a recent traveller in Somali Land (Georges Révoil), which he describes as being of the same colour, but more powerful odour, and easy of recognition from its always appearing oily. The main constituents of myrrh are some 40–75 per cent. of gum, 23–45 per cent. of resin, and a very uncertain quantity of essential oil. The gum is soluble in water; the resin partially in alkalies and carbon bisulphide, completely in chloroform and alcohol. The gum separated in making tincture may be used for making a common mucilage.

The principal exports of myrrh take place, as before stated, from Berbera; but several other ports participate in a minor degree. The drug is shipped from all parts of the Somali Coast to Mokha, Jedda, Aden, Makulla, the Persian Gulf, India, and China. Georges Révoil mentions 3 ports on the Medjourtine coast as receiving it for shipment:—Bender Gâsem, 30 *bohars* (of say 300 lb.) annually; Borah, 3 *bohars* annually; and Haffoûn, 25 *bohars* in 1877. This is mainly *bissa-bôl*, of which, Bombay, in 1872–3, received 224 cwt. from Aden, and shipped 138 cwt. to China. Some also finds its way overland to Brava (about 1° N. lat.) and Zanzibar. Aden exported 1439 cwt. of myrrh in 1875–6, about ½ going to Bombay, and ⅓ coming direct to the United Kingdom. The Bombay imports of *hira-bôl* in 1872–3 were:—16 cwt. from the African coast, 188 from the Red Sea, and 290 from Aden; the exports were 546 cwt., 493 being to the United Kingdom. Shanghai imported 331½ *piculs* (of 133⅓ lb.) of myrrh from Hong Kong in 1879. The approximate London market value of myrrh is 140–240*s.* a cwt. for good to fine, and 60–190*s.* for ordinary to fair. It is used largely in medicine, though possessed of no important powers; and in perfumery. In India, *bissa-bôl* is given to milch-cows and buffaloes to improve the milk-yield, and is used as a size and in incense.

Other *Balsamodendron* products are described under Balm of Gilead and Bdellium, pp. 1636–7.

Nagdana or Loban.—The resin bearing these names is produced by an undetermined species of Burseraceous tree in India. It has a deep transparent red colour, and exudes very freely during the hot months (March–April), much finding its way into the earth, and there concreting, to be dug up long after the tree has disappeared. Large masses are sometimes found after a forest fire.

Olibanum (Fr., *Encens*; Ger., *Weihrauch*).—The ignorance concerning the origin of myrrh is equally prevalent in the case of olibanum. The results of the very attentive study which Capt. Hunter has long devoted to the subject may be summarized as follows. There appear to be five different kinds or grades, two of which bear dissimilar names in E. and W. Somali Land. The names given are :—(1) *Mohr ad* or *mohr lafôd*, (2) *mohr madao*, (3) *mohr dadbêd* or *mohr as*, (4) *karâon*, (5) *yegaar*. (1) The first is obtained in strips sometimes 1 ft. long, though the *ad* is never so long as the *lafôd*; the plants yielding it are found on the coast range, especially near water-courses. The Kew authorities consider the *lafôd* plant to be probably a smooth-leaved form of *Boswellia Carterii*, while the *ad* plant is identified with *B. Bhau-Dajiana*, which may be itself an extreme form of *B. Carterii*. (2) The *madao* tree is comparatively rare, and its product is not highly esteemed, as it is sticky, and apt to discolour and depreciate other kinds when mixed with them. (3) *Dadbêd* and *as* are reddish-coloured, and afforded by a tree which is "common near the sea," but quite unknown to botany. (4) The *karâon* kind is but little valued, and is only added to the others as a make-weight; the tree is alleged to be rare, growing isolated on hill-tops. Nothing is known of it scientifically. (5) The produce of the *yegaar* or *gekar* plant (*Boswellia Frereana*) is kept quite distinct from the four preceding kinds (which are indiscriminately mixed), and is known as *mati* or *luban-mati* (variously spelt); it is likened by Capt. Hunter to the product of a Socotran tree called *amîru*, which is likewise unknown.

The region occupied by the trees yielding olibanum or true frankincense is defined by Carter as extending over that portion of Somali Land contained between the Sabhan mountains (in 17° 30′ N. lat., and 55° 23′ E. long.) and the town of Damkote, in the Bay of Al Kammar (in 52° 47′ E. long.). S. Arabia is said no longer to produce any. The plants affect two distinct localities: the Nedjee, or high land, 2 days' journey from the sea; and the Sahil, or plain on the coast. Capt. Kempthorne describes the trees on the coast of Adel as growing without soil, out of polished marble rocks, to which they are attached by a thick mass of the weathered rock, the growth of the trees appearing to be finer in proportion to the purity of the marble. The young trees are said to furnish the most valuable gum-resin, the older yielding a clear glutinous fluid resembling copal varnish. The fragrant gum-resin is distributed throughout the bark, leaves, and flowers of the plants. Its collection by the Medjourtine [Mijjertheyn] tribe of the Somalis is conducted as follows :—During the hot season, commencing about the end of February or beginning of March, the trees are visited in succession, and a deep incision is made in the stem of each, a narrow strip of bark being torn off for about 5 in. below the wound. After about a month, the old incision is deepened; and after the 3rd month, this is repeated. When the exudation is supposed to have attained the proper consistence, parties of men and boys go out and scrape the large globules into baskets, making a separate collection of the inferior quality which has run down the stems. As first removed from the trees, the gum-resin is very soft, but it soon hardens. The collecting is repeated every fortnight during the season, the crop increasing as it advances, till mid-September, when the first rain closes the year's harvest, and spoils a portion of the product. The collection of the gum-resin in S. Arabia, is (or rather was, for it is said to be now discontinued) performed by bands of Somalis from the opposite coast. Longitudinal incisions are made in the bark in May and December, when it appears much distended. The gum-resin issues as a milky fluid, and partly concretes on the stems beneath the incisions, partly falls on the ground. The Arabian article was always considered inferior to the African. The present supplies bearing Arabic names are said to be imported from Africa into the Arabian ports whence they are named.

Commercial olibanum fluctuates in quality and appearance. Speaking generally. it is a dry gum-resin consisting of long detached tears mingled with irregular lumps, and often with fragments of brown papery bark adhering. The colour is pale-yellow or brownish to greenish or nearly colourless. The smallest grains even are not transparent, but become so (or nearly so) by heating at 94° (201¼° F.). The fracture is dull and waxy, with no trace of crystallization. The gum-resin softens in the mouth, giving a turpentinous and slightly bitter flavour; the odour is agreeably aromatic, and much intensified by a high temperature. The composition may be generally stated as 4–7 per cent. of essential oil, 27–35 of gum, and the remainder of resin. The local classification and valuation of olibanum may be approximately given as follows :—(1) *Fessous* [*fasus*], a dry pure article, consisting of tears of powerful odour, exported from Ongar, and estimated at 30 dollars (of 2*s.* 11*d.*) per *bohar* (of variously 300, 440, and 450 lb.); (2) *naghua*, less pure, 20 dol.; (3) *wodjendel* [*madjendel*, *jandul*], very impure, containing much bark, 15 dol.; (4) *liban maheri* [*mascati*], quite white, a very rare article, 42 dol. The London market values are about the following :—Pale drop, 60–90*s.* a cwt.; amber and yellow, 40–85*s.*; garblings and siftings, 15–35*s.* The one important use of the gum-resin is for burning as incense.

Olibanum is shipped from most of the ports of the Somali country, but chiefly from Berbera, Bunder Mareyeh, and Zeila. The shipments from the Arabian coast between Damkote and Al Kammar are now unimportant, and said to be merely re-exports (received from African ports). The chief destinations of the gum-resin are Bombay and Aden, though Jedda is reported to receive some 12,000*l.* worth annually by way of the Straits of Bab-el-Mandeb. In 1872–3, Bombay imported 18,751 cwt., and re-exported 24,461 cwt., of which, 17,446 went to the United Kingdom, and 6184 to China. The Chinese imports in 1879 were 1124 *piculs* (of 133⅓ lb.) at Shanghai [they were 1360 in 1872], and 642 at Hankow.

There are other resin-yielding species of *Boswellia*, as follows:—(1) *B. papyrifera* [*Plösslea floribunda*], the *makar* of Sennaar and the mountainous region up to an altitude of 4000 ft. on the Takazze and Mareb rivers (Abyssinia), affords a transparent resin, which is not collected, and has no apparent value. (2) *B. glabra* and *serrata*, especially abundant on the trap hills of the Deccan and Satpura range, and readily propagated by cuttings, yield a soft, fragrant resin, which is locally used as incense, and called "Indian olibanum," or *dup salai.* 3. *B. Frereana*, a tree growing on the bare limestone hills near Bunder Mareyeh, an important village lying over 30 miles W. of Cape Gardafui. The trees are carefully guarded, and sometimes propagated. The resin, the "Oriental" or "African" elemi of older writers, and one of the resins anciently called "animi," exudes abundantly after incisions (which are made every week during the season), and is collected by the Somalis, and disposed of to traders for conveyance to Jedda and the Yemen ports. It occurs in detached tears, and in stalactitic masses of several oz., the tears being more esteemed by the natives. It has a brilliant conchoidal fracture, an agreeable odour of lemon and turpentine, an external, thin, white crust, and generally fragments of the papery bark of the tree adhering. It differs essentially in appearance from the other kinds of olibanum. It is largely used by the orientals as a masticatory and for incense, and arrives rarely in Europe with olibanum. Aden received 1928 cwt. in 1875–6, of which, ½ went to Egypt and Trieste, ¼ to Red Sea ports, ⅛ to the United Kingdom, and the rest to Bombay and the Danakil (Dankali) coast. Prof. Flückiger thinks it well fitted for any purpose to which common rosin, Burgundy pitch, and the allied resins or turpentines are applied.

Opopanax.—This gum-resin is attributed to *Opopanax Chironium*, a parsnip-like plant of S. Europe; the allied product of *O. persicum* obtained from Persia differs in appearance and odour, though the drug met with in Indian bazars is regarded as of Persian origin. It is now extinct in European medicine, and rarely met with, though apparently retaining considerable importance in native Indian and Chinese practice. The roots are taken up when the plant begins to sprout, and are broken off, the escaping juice being caught in leaves placed beneath, where it concretes in hard, nodular, earthy-looking, bright orange-brown lumps, of penetrating offensive odour. It consists mainly of about 42 per cent. of resin and 33 of gum. It is fusible at 50° (122° F.), and partially soluble in alkalies, alcohol, and ether.

Orange.—It is recorded that the stems of the members of the *Citrus* family afford a useful gum, said to be collected in the W. Indies; but such a product is unknown in commerce.

Peru Balsam.—(Fr., *Baume de Pérou, de San Salvador*; Ger., *Perubalsam*).—This misnamed gum-resin, the *balsamo negro* of the American Spaniards, and *hoo-sheet* of the native Indians, is produced almost (if not quite) exclusively by *Myroxylon* [*Myrospermum*] *Pereiræ*, a native of the so-called Balsam Coast, comprising the Indian Reservation Lands, forming a small district in the State of San Salvador, lying between 13° 35′ and 14° 10′ N. lat., and 89° and 89° 40′ W. long. Its only connection with Peru is the fact of its having been shipped viâ Callao to Europe in the early days of the trade. The trees grow in dense forests, and are often enclosed or marked by their owners, being valuable property. The principal Indian *pueblos* around which the balsam is produced are enumerated by Dr. Dorat (in 1863) as follows:—(1) Juisnagua, about 400 trees; (2) Tepocoyo, annual produce about 6 *arrobas* (of 25 lb.); (3) Tamanique, 1400 trees, giving some 160 *arrobas* yearly; (4) Chiltinapan, 2500 trees, affording 450 *arrobas* per annum; (5) Talnique, not more than 500 trees; (6) Jicalapa, about 1200 trees under cultivation, but many more in the uncleared woods; (7) Teotepeque, plenty of trees on the mountain slopes, but only 300 worked; (8) Comasagua, 1000 trees, but their cultivation giving way to coffee; (9) Jayaque, about 1000 trees under cultivation.

Concerning the secretion of the balsam, next to nothing is known. Early accounts speak of a superior article obtained by making incisions in the bark and probably reaching into the wood, but the present method of gathering the balsam is universally as follows:—After the last rains, in November–December, the trunks of the trees are beaten with some blunt instrument in four equidistant patches until the bark is loosened, a similar number of intermediate patches being left unbruised for the following year. The injured bark splits up, and may be easily detached; it already exhibits a slight exudation of fragrant balsam, but not sufficient to repay collection. To promote the flow, the bruised bark is charred some 5–6 days later by the application of bundles of burning wood, and after about another week, the charred bark either falls or is torn off, and the exudation begins in earnest. The wounds are then staunched by means of rags or cotton-wool, which absorbs the balsam; these, after a few days saturation, are collected and boiled in water. The greater part of the balsam is thus freed from them, and collects beneath the water, but the rags also undergo a rude wringing in a kind of rope bag, by which some further balsam is recovered from them, and added to the first. The contents of the boiler cool during the night, and next day the water is decanted, and the balsam is put up in *tecomates* (gourds) or other vessels for the market. The balsam thus prepared is locally known as *de trapo*. A small quantity of inferior grade is produced, according to Wyss, by boiling the bark in water; this is termed *de cascaro* or *tacuasonte*. The operation of collecting continues till May; it is suspended during the rains, but carried on more or less in the dog-days (15 July–15 August). The beating and staunching are only performed on four days of each week, giving 4 *cosechas* (harvests) a month. In the 2nd year, recourse is had to the patches left untouched from the first year. The bark renews itself in about two years, and it is thus possible to obtain an annual yield of about 2 lb. from the same tree for some 30 years, after which, if allowed 5–6 years' respite, it will again produce.

The balsam is a treacly liquid, of black colour in bulk, but deep orange-brown and transparent in a thin layer; its odour is balsamic and smoky, but fragrant and pleasant when developed by warming. Its sp. gr. is 1·15–1·16. Years of exposure to the air do not effect any change in it. It is only very slightly soluble in water, dilute alcohol, benzol, ether, and essential and fatty oils, and not at all in petroleum-spirit, but mixes readily with absolute alcohol, glacial acetic acid, acetone, and chloroform. The balsam contains about 32–38 per cent. of resin, the remainder being almost entirely cinnameine ($C_{16}H_{14}O_2$). An adulterated article is said to be largely prepared in Bremen. The balsam is mostly shipped at Acajutla, in San Salvador, about 40 miles from the Guatemalan frontier. The export in 1855 was stated at 22,804 lb., value 19,827 dollars (of 4*s.*); in 1876, the value was given as 78,189 dol. The London market value of the drug is about 7*s.* 6*d.* a lb. Its chief use is medicinal (see Drugs, p. 819); it is also employed in scenting soap.

The tree has been introduced into Ceylon, where it flourishes luxuriantly, but the balsam does not seem to have yet come into commerce from that island.

Besides tolu, which is the subject of a separate article (see p. 1684), there are several allied balsamic products demanding some notice. (1) The first that may be mentioned is the so-called "white" or "virgin" balsam, the *balsamo blanco* or *catolico*, or *balsamito*, a soft resin secreted in the large ducts of the fruit of the species just described, and extracted by expression. It is highly valued and scarce, and never sent into the market. (2) Much more important commercially is the fragrant balsamic resin collected from *Myroxylon peruiferum*, a large tree found in Tropical America, from S. Mexico to Peru, and even as far south as the Brazilian province of Rio Janeiro. It prefers moist mountain-valleys, up to 600 feet. The balsam extracted from the wood might, in the opinion of Theodor Peckolt, be conveniently substituted for the officinal balsam, especially as it mixes readily with castor-oil in all proportions. The exudation can be absorbed by cotton-wool, much in the same way as Peru balsam. In the fruit-pods, surrounding the seed, is found a small quantity of pale-yellowish aromatic oleo-resin, which is carefully preserved and highly prized under the name of *anguay do guaiani* or *balsamo do espirito santo*; it rarely enters commerce. (3) A balsam is obtained from incisions in the stem of the *oleo pardo* or *cabure-iba* (*Myrocarpus fastigiatus*).

Phormium.—Almost every portion of the plant *Phormium tenax* (see Fibrous Substances pp. 986–93), but especially the bases of the leaves, is replete with a gum which gives great trouble in the processes for extracting the fibre of the plant. The utilization of the gum deserves more attention than it has yet received, as it forms a mucilage capable of replacing that of gum arabic for most purposes.

Piney.—The copalline resins known as "white dammar," "piney resin," or "piney varnish" of S. India and Ceylon, and by some authors (e. g. Wiesner) termed "Manilla copal," are produced by two species of *Vateria*: *V. indica* of the W. Peninsula, from Canara to Travancore; and *V. acuminata*, common in the hotter part of Ceylon up to 2000 ft. The resin is obtained either by making incisions in the bark of the trees, and allowing it to exude and concrete; or by making excavations into the tree, where the liquid resin may collect. Sometimes masses of the hardened resin are found on splitting open old trees. When recently exuded, the resin is quite soft (then termed "varnish"), but it soon hardens into a brittle mass, varying in colour from bright-green to deep-amber, usually translucent, sometimes containing many air-bubbles. It is more soluble in alcohol than black dammar (see p. 1644); it dissolves readily in chloroform, and might serve the purposes of photographers' varnish; it has an advantage over copal in being quite soluble in turpentine and drying oils without preliminary fusion; its solution in turpentine is turbid, but the addition of powdered charcoal, and subsequent filtering, renders it transparent and colourless, and the solution mixes readily with the drying oils. The sp. gr. of the resin is about 1·121.

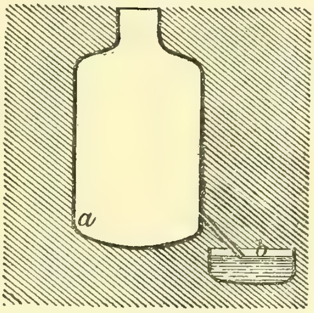
Somewhat similar products are said to be afforded by *Vatica* [*Vateria, Retinodendron, Seidlia*] *lanceæfolia* of E. Bengal, Silhet, Khasia, Assam, and Bhotan, and by *V. Roxburghiana* in S. Canara, Travancore, and Ceylon.

Other copals are described under Copal and Animi (pp. 1640–4), Dammar (pp. 1644–5), Jutahyseca (p. 1666), and Kauri (pp. 1666–7).

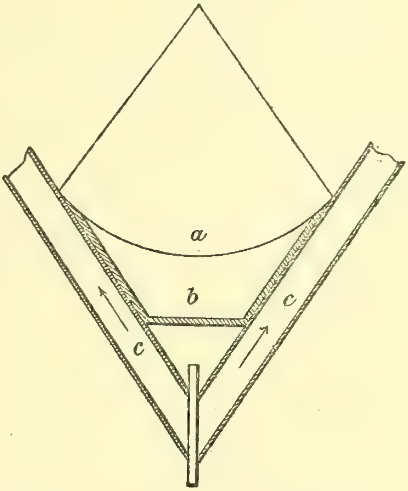
Pitches (Fr., *Poix*; Ger., *Pech*).—The term "pitch" embraces two products, "common" or "black," and "white" or "Burgundy." Mineral pitch, bitumen, or asphalt, has been described under the last name (see pp. 341–6).

1. *Common or Black Pitch* (Fr., *Poix noire*; Ger., *Schiffspech, Schusterpech, Schwarzes Pech*).—This article is produced by a further distillation of the tar obtained in the dry distillation of pine-wood (see p. 1683), and from the residues left in the boiler after the distillation of the crude turpentine to separate the rosin and spirit. The latter are heated in the open air, and filtered through straw mats, to afford a little more turpentine. These mats, charged with impurities and containing still a certain quantity of turpentine, were placed, according to the old plan, in a brick furnace (Fig. 1180); fire is kindled at the top, and the resinous matters escape by a pipe into the cooler *b*, a passage existing at *a* for the removal of the ashes. In works having the modern improvements, there only remains in the boiler (*b*, Fig. 1184) the residues which will not pass through the filter *d*, and the heavy matters settled below this orifice. These residues are filtered through mats, as by the old system, and afford a little turpentine. The mats are then placed in the apparatus shown in Fig. 1181, consisting of a double-lined trough, with steam circulating in the intermediate space *c*. The residues are placed on the metallic gauze tray *a*, and the box is covered to prevent evaporation of the spirit. Under the influence of the heat, the turpentine falls into the space *b*. It is then distilled in the apparatus shown in Fig. 1185, affording pitch, and a little spirit. The straw mats may finally be ignited in the brick chamber shown in Fig. 1180, thus producing a small quantity of tar, but they are more generally utilized as fuel.

1180.



1181.



Pitch is chiefly manufactured in countries which afford tar (see p. 1683), but also on a smaller scale in England. It is an opaque black substance, with shining conchoidal fracture, peculiar unpleasant odour, scarcely perceptible flavour, dissolving in the same menstrua as tar, and capable of being kneaded when softened by the heat of the hand. It is largely used in ointments, though probably devoid of medicinal properties. Its approximate London market value is 5–6*s.* a cwt. for British, and 7*s.* 6*d.* for Archangel. Our imports in 1880 were 63,430 cwt., value 16,687*l.*; our exports in the same year were 9967 cwt., 3420*l.* We imported 35,606 cwt. in 1876, and 81,558 in 1877. The imports for 1880 were contributed as follows:—Russia, 35,770 cwt., 9849*l.*; British W. Indies, 15,476 cwt., 1990*l.*; other countries, 12,184 cwt., 4848*l.* It is obvious that the W. Indian article is not pitch at all, but asphalt (see pp. 341–6), from the so-called Pitch Lake of Trinidad, and perhaps from Dominica as well. Our imports from Russia rose from 30,124 cwt. in 1876, to 47,269 in 1877. The total exports from Archangel were 15,209 barrels in 1874, 19,168 in 1875, 17,640 in 1876, 23,988 in 1877, 16,759 in 1878; the proportions taken by the several countries in 1878 were 9130 barrels by Great Britain, 1630 by Holland, 490 by France, 4175 by Italy, 1319 by Germany, and 15 by Norway. Boston (U.S.), in 1880, received 1848 barrels of pitch, and exported 3199. Wilmington (N. Carolina), in 1878, exported 4724 barrels, 331 going abroad; the aggregate value was 1600*l.* New York exported 5520 barrels in 1879. Hamburg, in 1881, imported 3492 tons, of which, 1346 came from Finland, and 2056 from Archangel. The Finnish port of Wiborg exported 207 barrels of pitch and tar, value 2900 Finnish marks (of 9½*d.*) to Norway, Germany, and England.

Burgundy Pitch (Fr., *Poix jaune, de Bourgogne, des Vosges*; Ger., *Fichtenharz, Tannenharz*).—This is a product of *Pinus Abies* [*Abies excelsa*], the spruce fir of Norway (see Timber—White Deal). It is prepared in Finland, the Black Forest, Baden, Austria, and the Bernese Jura (where it is called *poix blanche*). It is obtained from the trees by making perpendicular incisions in the stems about 1½ in. wide and deep; the exuding resin is scraped off by an iron instrument, and purified. This wounding of the trees causes so much injury to the timber that the collection of the resin is prohibited in the Government forests of Baden and Würtemberg. The purification is effected by melting the pitch either in contact with steam, or in hot water, and straining. In the latter case, the product (called *Wasserharz*) is opaque and highly charged with water, and needs to be improved by further straining and evaporation of the moisture. The production is not very great. Baron Linder's estate near Helsingfors (Finland) gave 689 cwt. in 1867, and an estate at Ihn, 1575 cwt. The Swiss forests yield about 900 *quintals* (of 220½ lb.) yearly. The pure pitch is opaque, yellowish-brown, hard, brittle, strongly adhesive, with a conchoidal fracture, and agreeable aromatic odour, It is employed in plaisters in this country; in Germany, mixed with colophony or thus, it forms the composition termed *Brauerpech*, used for lining beer-barrels.

The true pitch is very extensively replaced by an artificial compound, termed *poix blanche* in Belgium, and *poix blanche factice* in France. It is composed either of galipot melted in water, stirred, and filtered hot, or of a mixture of galipot (thus) or colophony with turpentine, turpentine-oil, or Bordeaux turpentine, coloured with palm-oil. The artificial article differs from the genuine in being completely soluble in alcohol, less tenacious and adherent, and of stronger and less fragrant odour.

Quebracho.—The so-called "gum" of *Quebracho colorado* is in reality an astringent extract, and will be described under Tannin.

Retinite.—This name was applied some years since to a species of fossil resin, found in small nodules and masses, sometimes in imperfect veins, in the brown coal and gold diggings at Caversham, Tarapeton, Waitahuna, and other parts of Otago (New Zealand); also in Borneo. It melts without decomposition, emitting an aromatic odour, and burns with a smoky flame; warmed gently with alcohol, it softens, and becomes very tenacious and adhesive. The sp. gr. is about 1·049. The colour varies from pale-yellow to dark-brown.

Rimu.—The *rimu* or *Dacrydium cupressinum* of New Zealand yields an exudation which can be converted into a varnish in no way inferior to copal.

Rosin or Colophony (Fr., *Colophane*, *Brai*, *Arcanson*; Ger., *Colophonium*, *Geigenharz*, *Gemeines Harz*) **and Rosin-oil.**—The several kinds of rosin, colophony, or resin proper are the solid residues obtained by the distillation of the turpentines (see pp. 1686–92). The crude turpentine or oleo-resin is submitted to aqueous distillation in a copper vessel, in place of the old-fashioned iron still which produced a red-coloured oil. The still, having a capacity of some 15 barrels (of 220 lb. each), is charged with crude oleo-resin in the early morning; heat is applied either by an ordinary furnace, or by a steam-jacket, until the mass attains a uniform temperature of 100°–158° (212°–316° F.). This is continued until the accidental water contained in the crude oleo-resin has been driven off, together with pyroligneous and formic acids, ether, and methylic alcohol, the whole being known as "low wine." This accomplished, a small stream of cold water is admitted, so that the heat is kept at or below 158° (316° F.), the boiling-point of turpentine-oil. The distillation continues, a mixture of water and turpentine-oil passing over into a wooden separating-tub; this is merely a tub with two outlet taps, one near the bottom, the other about half-way from the top, the difference in sp. gr. of the two bodies permitting their withdrawal into separate receptacles. The progress of the distillation is judged by means of samples taken at intervals in a graduated measure; when the liquid shows 9 parts of water to 1 of turpentine-oil, the distillation is stopped, the still-cap is removed, and the hot rosin remaining in a fluid condition in the still is drawn off by a tap near the bottom, and passed through a fine strainer into a vat, whence it is baled by long-handled wooden buckets into barrels for sale.

The grade of the rosin depends (1) upon the quality of the crude oleo-resin under treatment, and (2) upon the skill with which the operation is conducted. The so-called "virgin turpentine," the first exudation from a newly-chipped tree, will give "window-glass" rosin of varying quality; "yellow dip," the runnings of the second and subsequent years, affords medium grades of rosin; while "scrapings," the inspissated gum from the tree facings (see Thus, p. 1684), yields an inferior dark rosin. Black rosin is not caused by burning in the still, as has been stated. Opacity is due to the presence of water, by which, crystals of abietic acid are formed. Every turpentine produces its own peculiar rosin. That most common in continental Europe is obtained from Bordeaux turpentine (see p. 1687); in England and America, that derived from the latter country holds the foremost place. Speaking in general terms, rosin is an almost flavourless body, of faint but characteristic odour, and varying in colour from the palest amber to the deepest black, and from translucent to opaque. Common yellow rosin is homogeneous, amorphous, very friable, and of sp. gr. 1·07; it softens at 80° (176° F.), and fuses completely to a limpid yellow liquid at 100° (212° F.). It is insoluble in water, but soluble in acetone and benzol in nearly all proportions, in 8 parts of alcohol of 88° at 15°–20° (59°–68° F.), and pretty freely in ether and fatty oils. Treated with boiling alkaline solutions, it takes up the elements of water to form abietic acid, which then unites with the alkali present to form rosin-soap (see Soap). The rosin of Venice turpentine (see p. 1691) dissolves in 2 parts of hot alcohol of 75°. That of Canadian turpentine (see p. 1686) consists of two ingredients, one (78·7 per cent.) soluble in boiling absolute alcohol and glacial acetic acid, and the other (21·3 per cent.) soluble in ether; both the turpentine and the rosin are insoluble in caustic alkalies. The rosin of Strassburg turpentine (see p. 1691) is completely soluble in glacial acetic acid, but incompletely in acetone and absolute alcohol. Medicinally, rosin is employed in plaisters; industrially, in the manufacture of rosin-soap, sealing-wax, varnishes, and cements, and for soldering metals. The approximate London market value is 5–15*s.* a cwt.

The commerce in rosin is considerable. Our imports in 1880 were 1,051,825 cwt., value 323,319*l.*, from the United States, and 31,577 cwt., 13,468*l.*, from other countries; total, 1,083,402 cwt., 336,787*l.* Our exports in the same year were 31,491 cwt., 10,593*l.* The imports from America have not fluctuated much during late years, having been 966,109 cwt. in 1876, and 1,105,367 in 1879. The imports from France were 13,851 cwt. in 1876, 6389 in 1877, 37,840 in 1879, and 29,278 in 1880. Recent details of American shipments are as follows:—New York: 157,834 barrels (of 220 lb.) in 1879; 234,778 in 1878, being 51,753 to Great Britain, 5166 to France, 101,009 to N. Europe, 16,019 to other Europe, 60,831 to S. America, E. and W. Indies, &c. Mobile: in 1878, exports abroad, 49,247 bar., 17,448*l.*; sent inland and coastwise, 67,630 bar., 23,604*l.*; in 1880, exports, 18,795 bar., 9582*l.*; inland and coastwise, 27,140 bar., 14,019*l.* Savannah: exports, 85,551 bar. (42,443 being to English ports) in 1879; in 1880, exports, 77,339 bar., 57,478*l.*, and coastwise, 141,435 bar. Boston: in 1878, received 17,556 bar., exported 4032; in 1880, received 22,732 bar., exported 5038. New Orleans: exports, 1880, 821 bar. Philadelphia: exports, 1879, 3310 bar. Baltimore: exports, 6735 bar. in 1877, 3120 in 1879, 13,031 in 1880. Wilmington (N. Carolina): in 1878, 516,279 bar. exported, and 65,679 coastwise; total value, 162,518*l.* The Italian port of Venice despatched 557 tons, value 4462*l.*, in 1878, and 560 tons, 4487*l.*, in 1879. Of Chinese ports, Hankow shipped 2055½ *piculs* (of 133⅓ lb.) in 1878 and Wenchow, 25 *piculs* in the same year.

The preparation of rosin for soap-making purposes is described under Soap.

Rosin-oil.—This product, to which frequent allusion is made in the article on Oils and Fatty Substances, notably in the section relating to Detection and Analysis (see pp. 1467–9, 1476), is manufactured in the following manner. The rosin, usually of the lower grades, is introduced into an iron still, and heated up to 158°–160° (316°–320° F.). Water, pyroligneous acid, and naphtha pass over at first, and until the rosin is exhausted of naphtha. The temperature is then raised to near the red-heat of iron, when the rosin boils, and crude rosin-oil distils over. It is a heavy, nearly opaque, whitish, viscid fluid, opalescent on the surface. It is rectified by redistillation, and the resulting oil is transparent, dark-red by transmitted light, with a bluish cast by reflected light, and sometimes highly opalescent.

Sagapenum.—The origin of sagapenum is wrapped in obscurity. It is supposed to be produced by a species of *Ferula*, and *F. persica* has been especially pointed to, but nothing certain is known on the subject. The locality affording it cannot even be indicated, though there is reason to suppose that it comes from Persia and the countries to the east, the village of Máh, near Ispahan, being particularly referred to. The drug is now extremely rare, and scarcely to be had in a pure state even in Bombay; formerly it would seem to have been plentiful. It is a gum-resin, forming a tough softish mass of strongly agglutinated small tears, of brownish colour, manifesting no pink hue when broken, nor an alliaceous odour, but acquiring a most intense and permanent blue colour when immersed in cold hydrochloric acid of 1·13 sp. gr. More rarely it occurs in translucent yellowish-brown tears, varying in size from a hazel-nut to a walnut. These characteristics serve to distinguish it from ammoniacum, galbanum, and opoponax, which it otherwise resembles, and which are often substituted for it by the native druggists of India.

Sandarach (Fr., *Sandaraque*; Ger., *Sandarac*).—Sandarach when in powder is termed "pounce"; it has also been called "juniper-gum" or "-resin," from the erroneous supposition that it was afforded by *Juniperus spp.*; and the closely allied Australian product has been introduced as "pine-gum."

The tree affording sandarach is *Callitris quadrivalvis* [*Thuja articulata*, *Frenela Fontanesii*], remarkable for its wood (see Timber—Alerce); it is indigenous to the mountains of N. Africa, from the Atlantic to E. Algeria, its eastern limit being undetermined. The resin exudes naturally from the bark of the stem, but the common practice is to make incisions in the stem, particularly near the base, by which the flow is much increased. The juice rapidly hardens on exposure, and is collected by the Moors, and carried by them to Mogador for export to Europe. It occurs in commerce mostly in cylindrical tears, which are occasionally agglutinated. Its colour is pale-yellow to pale red-brown, the best being very clear and transparent. The exterior often appears "powdery," from the occurrence of innumerable fissures by unequal contraction in drying. It has about the same hardness as kauri, softens at 100° (212° F.), and melts and swells at 150° (302° F.); its sp. gr. is 1·066–1·092, the fracture is clean and shiny, and the odour is weak and aromatic, increasing with heat. It is not softened by boiling water, and is not soluble in caustic soda or acetic acid; it is partially soluble in benzol, rectified petroleum, chloroform, and turpentine-oil, very slightly in carbon bisulphide and boiling linseed-oil, but completely in alcohol and ether. Sandarach is said to be adulterated with gum arabic, but this seems doubtful; more commonly it is itself substituted for mastic, from which it may be distinguished by the softness of the latter, its complete solubility in turpentine-oil, and incomplete in cold alcohol. Formerly of wide renown in medicine, the resin is now valued, in Europe at least, principally as an ingredient of varnishes, to increase the hardness and glossiness; powdered, under the name of "pounce," it is used for preparing the surface of parchment and paper to receive writing. Its approximate price in the London drug market is 60–115*s.* a cwt.

The Australian species of *Callitris* yield a resin which can scarcely be distinguished from the African. The principal species seem to be *C. verrucosa* [*Frenela crassivalvis*], *C. cupressiformis*, and *C.* [*F.*] *robusta.* They are abundant on the sandy tracts of the Murray River (Victoria), and are scattered more or less throughout the whole continent, being recorded from King George's Sound and Shark Bay (W. Australia), and from Arnhem Land (N. Australia). The resin might easily become an article of local commerce, if not of export.

Sarcocolla.—The plant and country affording this medicinal gum-resin are unknown. It has been referred to a *Penœa sp.*, found only in the Cape, but this is obviously incorrect. Dr. Dymock believes it to be produced by one of the desert *Leguminosæ*, probably an *Astragalus.* Native evidence ascribes it to Persia and Turkistan; this is borne out by the fact that the Bombay imports of the drug, which are considerable, come entirely from Bushire, in the Persian Gulf. It arrives in bags containing about 2 cwt., always largely intermixed with remains of the plant (except leaves) and with sand, whence Dymock supposes it to be collected by beating the bushes after the leaves have fallen, and allowing it to accumulate upon the ground. It holds an important place in Indian native pharmacy.

Satin-wood.—The satin-wood tree of India and Ceylon (*Swietenia Chloroxylon*) occurs in fractured and agglutinated tears, brittle, brown, translucent, and soluble in water, giving a turbid, dark mahogany-coloured mucilage, having an odour of fusel-oil. It is not a commercial article.

Scammony.—See Drugs, pp. 823–4.

Schaufite.—This name has been applied to a fossil resin found in some abundance in schistose sandstone beds traversing the petroleum region in Bukowina, Galicia, Bohemia, and S. Austria. It forms veins of ½–4 in. in thickness. The colour is purplish to blood-red, and the hardness sufficient to admit of polishing, but not turning. It is slightly soluble in alcohol, benzine, and chloroform, entirely in sulphuric acid, and is saponifiable by caustic alkali. Distilled, it leaves a reddish-brown colophony, giving a brilliant varnish with turpentine and fatty oils.

Storax (Fr., *Styrax*; Ger., *Storax*).—Several products call for description under this head, the most important being liquid storax or liquidambar.

Liquid Storax.—This is obtained from *Liquidambar orientale* [*imberbe*], a plane-like tree forming forests in S.-W. Asia Minor, notably near Melasso, about Budrum and Monghla, near Giova and Ulla, by Marmorizza and Isgengak in the valley of the El-Azi, and possibly near Narkislik, a village near Alexandretta; but it is unknown in the islands of the Mediterranean. The resin is collected by the Yuruk nomads, by first removing the outer bark, and then scraping away the resinous inner bark, accumulating it in some quantity in pits. This bark is then either pressed dry in the first instance, or at once boiled with water in large copper vessels, whereby the resin is separated and can be skimmed off. The boiled bark is packed in hair bags and subjected to pressure while hot water is poured over. Thus a second quantity of resin is procured. The water used in the boiling is probably from the sea or saline lakes, as attested by the presence of salt in the drug. The result of the process is an opaque, grey, semi-fluid resin, of pleasant balsamic odour after long keeping, and pungent burning aromatic flavour; and cakes of fragrant brown bark, which, coarsely powdered, is mixed up with storax, honey, and other substances, into an odoriferous compound, of which there are many qualities. Some 25 years ago the production of the resin was computed at about 800 cwt. per annum. It is mostly exported in casks by way of Constantinople, Smyrna, Syra, and Alexandria; some is packed with water in goat-skins for transport to Smyrna, and sent thence in barrels to Trieste. The use of the resin in this country is trifling and wholly medicinal (see Drugs, p. 826); the chief markets for it are India and China. Scherzer (1880) states the exports from Smyrna at 25,000–30,000 *okes* (of 2·83 lb.), worth 7 *piastres* (say 1*s.* 3*d.*) the *oke*, chiefly for China and Egypt, for use in perfumery, fumigation, and church incense. It is said to have been employed in the United States as an adulterant of tolu.

True Storax.—True storax was a benzoin-like fragrant resin, afforded by the stem of *Styrax officinale*, of Greece, Asia Minor, Syria, Italy, and S. France; it has ceased to be produced since the trees have been reduced to mere bushes by cutting.

American Liquidambar.—This is derived from *Liquidambar styraciflua*, a large tree of the American continent, from Connecticut and Illinois southward to Mexico and Guatemala. In the United States, small quantities of a balsamic resin, termed "sweet gum," and sometimes used as a masticatory, are collected from natural fissures or incisions made in the tree. In Central America, the exudation is much more freely afforded, and is collected by the Indians in small cylinders, to be burnt as incense. As met with in commerce, it is a transparent, thick, fluid, golden-brown oleoresin, of balsamic odour, and similar flavour.

E. Asian Liquidambar.—This is of two kinds. The first is a dry terebinthinous fragrant resin produced by *L. formosana* in Formosa and S. China; it is used by the Chinese. The second is a fragrant balsam obtained from *L. Altingiana* [*Altingia excelsa*], of Assam, Burma, and the E. Archipelago. It is collected in small quantity in Java from incisions in the trunk; in Burma, a pellucid light-yellowish kind is procured in the same way, besides a darker, thicker quality by boring the stem and applying fire around it.

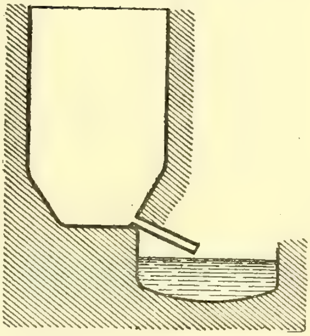
Tamanu and Tacamahaca.—The name *tamanu* is applied only to the resin of *Calophyllum inophyllum*, but *tacamahaca* (variously spelt) is used indiscriminately for the resins of *Icica Tacamahaca, Calophyllum inophyllum, Elaphrium tomentosum, Populus balsamifera*, and *Calophyllum Calaba*. In the present article, the terms will be restricted to the resins of *Calophyllum spp.*, particularly *C. inophyllum*. The geographical distribution of this tree has been given elsewhere (see Oils and Fatty Substances—Dilo, pp. 1387–8). The resin exudes both spontaneously and from incisions in the bark and roots. It is green or yellow and liquid when first it escapes, but hardens in time to a brittle aromatic mass, soluble in alcohol and ether. *C. Calaba* seems to yield a similar article in Venezuela. The Venezuelan port of Maracaibo shipped 583 lb. of tacamahaca, value 176½ dol. (of 4*s.* 2*d.*) in 1880.

Tars.—The tars here to be considered are the so-called "wood-tars," obtained by submitting the wood of the stems and roots of certain trees to a process of destructive distillation. They are of several kinds, and will be described in the following alphabetic order:—(1) Archangel or Stockholm, (2) beech, (3) birch, (4) dummele, (5) ganda, (6) juniper, (7) teak.

1. *Archangel or Stockholm Tar* (Fr., *Goudron végétal, Poix liquide*; Ger., *Holztheer, Fichtentheer*).—This, by far the most important of the vegetable tars, is produced in Finland, Central and N. Russia, and Sweden, chiefly from *Pinus silvestris* and *P. Ledebourii* [*Larix sibirica*] (see Timber), constituting the forests of Arctic Europe and Asia; and in America, from *P. mitis, P. rigida, P. australis*, and other species. N. Europe is much the larger producer.

The process of distillation is commonly performed as follows. The roots and bases of the trees, which are valueless as timber, are closely packed in huge stacks (30,000–70,000 cub. ft.), and covered with a thick layer of turf, moss, and earth, heavily beaten down. The stack is built over a conical cavity in the ground, and if possible on a hill-side. A section of the oven and receiver is shown in Fig. 1182. Fire being applied, combustion is allowed to proceed very slowly and without flame, requiring 1–4 weeks for its completion, according to the bulk of the stack. The products of the downward distillation (mainly tar) collect in the cavity, and are discharged thence into receptacles. A great improvement on this rude plan is the employment of wrought-iron stills with refrigerating condensers. By their use, the yield of tar obtained from air-dried pine-wood is 14 per cent., and from the roots, 16–20 per cent.; in addition, much pyroligneous acid and turpentine-oil is saved. Tar is usually transported in barrels of 31½ gal. Its approximate London market value is 13–17*s.* a bar. for Archangel, and 18*s.* for Stockholm. Its widespread use as a preservative application to wood is sufficiently familiar.

1182.



Our imports of tar in 1880 were 105,449 bar., value 73,772*l.*, from Russia; 10,719 bar., 7138*l.*, from the United States; 3877 bar., 3219*l.*, from Sweden; and 11,227 bar., 6465*l.*, from other countries; total, 131,272 bar., 90,594*l.* Our exports in the same year to all countries were 9740 bar., 10,048*l.* The imports show a gradual diminution in quantity from 174,679 bar. in 1877; and in value, from 152,969*l.* in 1876. Russian tar is manufactured in Finland and shipped from various ports in the Gulf of Bothnia (Uleaborg, Gamla and Ny Carleby, Jacobsstad, Christinestad), and from Archangel and Onega on the White Sea; while some is produced in Volhynia, and finds its way by the Dnieper to the Black Sea. The Swedish localities of production are mainly about Umea and Lulea, where iron stills are in general use, thus accounting for the superior price of Stockholm tar. Our imports from Sweden fell from 8083 bar. in 1877, to 701 in 1878, and recovered to 4319 in 1879. Our imports from the United States were 29,771 bar. in 1877, since which date they have constantly receded. New York exported 7679 bar. in 1878, and 7031 in 1879; of the former, 1050 bar. went to N. Europe, and 6070 to S. America, E. and W. Indies, &c. Philadelphia, in 1879, exported 1968 bar. of tar and pitch. Boston, in 1880, received 8398 bar., and exported 1088. Wilmington (N. Carolina), in 1878, sent 32,008 bar. coastwise, and 31,176 abroad; total value, 19,461*l.* The exports of tar from Finland were 143,174 bar. in 1878, 138,730 in 1879, and 129,669 in 1880.

2. *Beech-tar.*—The wood of the beech, *Fagus sylvatica* (see Timber), affords about 10 per cent. of tar, which is considered by some authorities the best source of creasote.

3. *Birch-tar.*—The wood and bark of *Betula alba* afford a tar whose chief importance lies in its being the source of the empyreumatic oil used in the preparation of Russia-leather (see Oils and Fatty Substances, pp. 1417–8).

4. *Dummele.*—This name is applied in Ceylon to a tar extracted by the moormen from the wood of *Sethia indica* [*Erythroxylon monogynum*], of the Circars, Travancore mountains, Mysore, Malabar, and Ceylon. The wood is packed into an earthen pot (*chatty*) with a narrow mouth; this is inverted over a second pot, and surrounded by fire. The tar thus distilled is soluble in ether, alcohol, and turpentine, and is an excellent preservative of timber. It is not a commercial article, but might become so.

5. *Ganda.*—The natives of the Himálayas prepare a tar from dry chips of the *ganda* tree (*Pinus longifolia*) of their district. The process is much the same as with *dummele.* The product from this species and *P. excelsa* and *Cedrus Deodara*, with due care, is said to be quite equal to the Stockholm tar imported from Europe, and much cheaper.

6. *Juniper-tar* (Fr., *Huile de Cade*).—This was originally obtained by the destructive distillation of the wood of *Juniperus oxycedrus*, a native of the Mediterranean region. The modern article is of doubtful origin, and much resembles Stockholm tar.

7. *Teak-tar.*—The wood of *Tectona grandis* (see Timber—Teak) yields about 5 per cent. of tar by the crude native method of distilling it. The wood is best used 3 months after felling. Probably the roots would yield much more. It is only used medicinally by the natives of some parts of India.

A tar is also extracted by the Moors from the root of *Callitris quadrivalvis* (see Sandarach), and applied to wounds on draught animals.

Tendoo and Gaup.—These names are applied respectively to a resin from the trunk and a gum from the fruit of *Diospyros glutinosa* [*Embryopteris glutinifera*], a native of the Indian Peninsula, Travancore, Assam, and Bengal. Both products are said to be used for caulking boats, and preserving fishing-nets, but they are not objects of commerce. Further research as to their supply and applicability is desirable.

Thus, Scrape, or Common Frankincense (Fr., *Galipot, Barras*).—These terms are applied to the turpentine which concretes upon the trunks of the various species whence that oleo-resin is derived (see pp. 1686–92). In the French department of Landes, the collection is commenced immediately after the conclusion of the turpentine-harvest. The impoverished exudation from the latest wounds, escaping when the air-temperature is not high, and being probably less rich in essential oil, dries in stalactitic masses, reaching from the incision to the base of the tree. These are separately collected in the winter. In France, the term *galipot* is restricted to the concretions along the scars, which can be gathered without admixture with bark fragments; while *barras* is applied to those portions which can only be detached by scraping, and are thus much contaminated with woody débris. The commercial article occurs in solid or softish masses, yellowish-white to greenish in colour, granular in texture, and completely soluble in alcohol. It differs from the turpentines mainly in containing less essential oil, and is used for similar purposes. Its approximate London market value is 16–20*s.* a cwt.

Tolu (Fr., *Baume de Tolu*; Ger., *Tolubalsam*).—This balsam or rather resin is afforded by *Myroxylon Toluifera* [*Toluifera Balsamum, Myrospermum Toluiferum*], a native of Venezuela and New Granada (Colombia), probably also of Brazil and Ecuador, and identical, according to Bentley, and Trimen, with *Myroxylon punctatum*, an inhabitant of nearly the whole northern part of S. America. Weir is of opinion that the tree is plentifully scattered throughout the *montaña* around Plato and other small ports on the right bank of the Magdalena. Another writer states that the balsam is largely collected in the Sinu valley, and the forests separating that river from the Cauca; but none seems to be gathered in Venezuela. The tree is never found in the low tracts adjoining the rivers, but in the higher rolling ground beyond, where the soil is dry. The balsam-harvest lasts about 8 months, from July to March–April. The collection is effected by V-shaped incisions, at the apex of which, a little hollow is made in the bark and wood, to facilitate the fixing of tea-cup-like calabashes, as receptacles for the exudation. About 20 incisions are commonly made within the space accessible to a man standing on the ground; when this portion of the trunk affords no further space for new incisions, a higher section is sometimes attacked by the aid of a rude stage. The contents of the calabashes are emptied at intervals—(they fill in one month when the flow is good)—into hide bags slung on donkeys, for conveyance to the river-ports, where the balsam is transferred to cylindrical tins of about 10 lb. capacity for export. In some districts no calabashes are used, the exudation finding its way down the trunk into a large *Calathea*-leaf.

The balsam is a light-brown, viscid or fluid resin, gradually hardening to brittleness, but readily softened by warmth; of sp. gr. 1·2, agreeable odour, and slight aromatic flavour. It is soluble in alcohol and chloroform completely, and in ether partially; but is very slightly dissolved by essential oils and carbon bisulphide, whence the detection of such adulterants as rosin is rendered easy. The use of liquid storax (see p. 1682) as an adulterant is said to occur in the

United States. It is employed slightly in medicine, but more in perfumery. Its London market value is about 3–4*s.* a lb. It is exported from Colombian (New Granada) ports:—The shipments from Santa Marta were 2002 lb. in 1870, 2183 in 1871, and 1206 in 1872; and from Savanilla, 27,180 *kilo.* in 1876.

Tragacanth.—Using the term "tragacanth" in a generic sense, the species to be described are:—(1) Tragacanth proper, (2) Indian tragacanth, or *kuteera*, (3) African tragacanth, (4) Hog tragacanth, or simply "hog gum," which must be distinguished from the gum bearing the same name described on p. 1654.

1. *Tragacanth proper* (Fr., *Adragante*; Ger., *Traganth*).—True tragacanth is a gummy exudation afforded by the stems of several species of *Astragalus*, of which the principal are the following:—*A. gummifer*, occurring on Lebanon and Hermon in Syria, Beryt Dagh in Catalonia, Arjish Dagh (Argæus) in Central Asia Minor, and in Armenia and N. Kurdistan; *A. microcephalus*, extending from S.-W. Asia Minor to Turkish and Russian Armenia; *A. adscendens*, a native of the mountains of S.-W. Persia at 9000–10,000 ft.; *A. brachycalyx*, on the mountains of Persian Kurdistan; *A. pycnoclados*, on the high mountains of Avroman and Stahn, Persia; *A. kurdicus*, on the mountains of Cilicia and Cappadocia, extending thence into Kurdistan; *A. stromatodes*, at 5000 ft. on the Akker Dagh range, N. Syria; *A. verus*, in N.-W. Persia and Asia Minor; *A. Parnassi*, var. *cylleneus*, on the northern mountains of the Morea; and *A. leioclados*.

The mode of secretion of tragacanth has been discussed under the generalities commencing this article (see p. 1620). Reference must here be made to Giraud's researches, quoted in the Bibliography at p. 1695, which throw quite a new light upon the subject; according to his analysis, tragacanth contains only 8–10 per cent. of soluble gum, and about 60 of pectinous principle, apparently identical with Frémy's pectose. The collection of the gum in Asia Minor and Armenia is described by Tozer, Maltass, Hamilton, Von Scherzer, and others. The principal localities for it are the district of Angora; Isbarta, Buldur, and Yalavatz, north of the Gulf of Adalia; the Ali Dagh range between Tarsous and Kaisarieh, and the hilly country eastward as far as the Euphrates valley; the elevated Bingol Dagh range, south of Erzeroum; and throughout Kurdistan, from Mush for 500 miles in a S.-E. direction to the Persian province of Luristan. About the first week in August, the gum is seen adhering to the stems and branches, looking from a distance almost like down, but later in the season it usually has fallen off, so that the ground below is strewn with it. The common way of obtaining it, however, is to cut the plant and leave it to bleed; after some days, when the gum has exuded and hardened, the collectors return and gather it. The ground is often swept clean to receive the droppings. The incisions are sometimes cuts made into the bark, sometimes simply punctures with a knife-point. In Persia, the production of the gum is spread over an area of 300 miles long by 100–150 broad, between Gilpaigon and Kashan, southward to the Mahomed Suma range, N.-E. of Shiraz. The tragacanth collected in Persia and Kurdistan is mostly of spontaneous exudation.

The composition of tragacanth has already been stated. The best samples are dull-white, translucent, lustreless, flexible, strong, odourless, and almost flavourless. It occurs in two principal forms, distinguished as "leaf" and "vermicelli." The latter consists of vermiform pieces; the former, of flattish strips, 1–3 in. long and ¼–1 in. wide. Immersed in water, it swells up and finally disintegrates. It is readily soluble in alkaline liquids. Its chief use is for imparting firmness to lozenges and pill-masses, and in other pharmaceutical preparations; the commoner kinds are employed in a mucilage for "marbling" books. The approximate London market values are 10–20*l.* a cwt. for leaf, and 2–10*l.* for low to good sorts, the price depending upon the purity and whiteness. One of the chief export marts is Smyrna, whither it is brought from the interior (Kaisarieh, Konieh, &c.) in a very crude state in bags of about 2 *quintals*, in August, and where it is largely assorted by Spanish Jews for the European market. The annual export from Smyrna is stated at about 4500 *quintals* (of 100 lb.), value 65,000*l.* It is also shipped from Constantinople and the Persian Gulf. The Persian and Kurdistan article is despatched from Bagdad, which sent 555 cwt., value 2259*l.*, to India and Europe in 1878. This article is erroneously termed "Syrian" in English drug sales. Mersine [Musyna] exported 245 tons, value 31,800*l.*, in 1880.

2. *Indian Tragacanth or Kuteera.*—Gums bearing a close resemblance to tragacanth are produced by several Indian plants. One of the most important is *Cochlospermum* [*Bombax*] *Gossypium*, a native of the dry hills of Garhwal, Bundelkund, Berar, Orissa, and the Deccan, also commonly planted near temples. The gum is white, semi-transparent, in striated pieces which are very much twisted and contorted; it is used locally by shoemakers. This variety is considered inferior to the gum yielded by *Sterculia* [*Cavallium*] *urens*, a native of N.-W. India, Assam, Behar, the E. and W. Peninsulas, and Ceylon. Several other species of *Sterculia* are accredited with affording an almost identical product. The range of utility of this class of gums is very limited, competing only with the lowest grades of true tragacanth, for which there is but slight demand in European markets.

3. *African Tragacanth.*—This variety is derived from *Sterculia Tragacantha*, an abundant native of W. Africa, from Senegambia to the Congo. The gum is afforded in great quantity, and commonly finds its way into parcels of Senegal (Arabic) gum. It forms colourless or yellowish stalactitic masses, transparent in very thin slices. It bears the closest general resemblance to the produce of Indian species of *Sterculia*, just described.

4. *Hog Tragacanth, or Hog Gum.*—These terms, like that of "Bassora gum," seem to be applied to mixtures of various cheap and inferior gums, placed on the market at intervals with a view to being foisted off as tragacanth. At Smyrna, tragacanth is mixed with gums termed "Mosul" and "Caramania." The former appears to be very inferior tragacanth; while the latter is referred to the exudations of almond- and plum-trees, and is usually treated with white-lead to hide its darker colour. It is evident that the Indian *Sterculiæ* also contribute occasionally to the supplies of hog tragacanth. Almost the only application of this inferior material is as a mucilage for "marbling" book-edges, for which purpose it is not superior to mucilages obtained from linseed, quince-seed, or elm-bark. (See also Hog gum, p. 1654.)

Turpentine.—This name is applied to a number of liquid oleo-resins obtained chiefly from the *Coniferæ.* They will receive separate description in the following order:—(1) Aleppo, (2) Canadian, (3) Carpathian, (4) Chian, (5) Common, (6) Hungarian, (7) Strasburg, (8) Venice.

1. *Aleppo turpentine.*—The Aleppo pine (*Pinus Halepensis*) in Provence is tapped much in the same way as the maritime pine in W. France, and yields similar but less valuable products. Usually the tree is bled when it has attained a diameter of 8–12 in. The incisions (*surlés*) are about 4 in. wide, and are prolonged by a fresh cut upwards once every 19 days, till their length amounts to about 1 ft. The exudation is received in holes made in the ground at the foot of the tree. Freshly caught, it is called *périme vierge*; the cakes of resin prepared from it are termed *rare.* The yield of a good tree should be 13–15 lb. of crude turpentine annually for about 20 years.

2. *Canadian turpentine* (Fr., *Baume du Canada, Térébinthine du Canada, T. du Sapin baumier, Faux baume de Giléad*; Ger., *Canada balsam*).—Canadian turpentine, or, as it is generally called, "Canada balsam," is produced by the "balsam fir" or "balm of Gilead fir" (*Pinus* [*Abies*] *balsamea*), and in a minor degree by the "small-fruited" or "double balsam fir" (*P. Fraseri*), and a closely similar article by the hemlock spruce (*P.* [*A.*] *canadensis*). The first species is very abundant in the N. and W. United States, Nova Scotia, and Canada, up to 62° N. lat. The second occurs on the mountains of Pennsylvania, Virginia, and southward on the highest Alleghanies. The third (see Tannin) extends throughout British America to Alaska. Of these three, the first only will receive further description here.

The balsam fir prefers wet or marshy soil, in cold hilly regions, though thriving on comparatively dry upland, and in almost any soil. Its growth is rapid, but its size is small—30–40 ft. high, and 6–8 in. diam. It is thus of little value for timber, and is utilized only for its oleo-resin, which is generally more abundant in the flourishing smooth-barked trees of low damp lands than in the stunted growths of the mountains. The tree is very subject to the attacks of a bark-mining beetle, belonging to the genus *Tomicus*, which is rapidly destroying the forests, and can only be checked by felling all trees that are affected, burning the bark and with it the colonies of larvæ.

The oleo-resin collects in utricules, which cause a protuberance in the exterior layers of the bark. The tapping is performed in a peculiar manner. The gatherers are provided with small cans, having a sharp-edged iron tube proceeding from the top. By this tube, the blisters are pierced one by one, the liquid flowing down the tube until the can is full. Boys are sent up into the branches, while the father works about the lower part of the tree, this industry being followed by families, and confined to the poorest colonists and the Indians. A large rich tree may yield 1 lb. of oleo-resin, but the average is about ½ lb. A man and 2 children may collect 1 gal. in a day, while a man alone would not exceed ½ gal. The gathering cannot be prosecuted during rain, nor even in the same day, as drops of water mixing with the exudation render it milky and unsaleable. The season lasts from about 15 June to 15 August or 1 September, or between the dates of the disappearance of snow from the mountains and its reappearance. Near the villages and on partially cleared land, small quantities are collected in May. A tree should not be pierced in two successive years; 2–3 years' rest should intervene, and even then the subsequent yield never equals what it was the first time.

The freshly-drawn oleo-resin is a honey-like, transparent, straw-coloured to greenish body, slowly thickening and darkening by keeping, but always retaining its transparency, and never crystallizing. Its odour is pleasant and aromatic; its flavour, bitterish and feebly acrid, but not objectionable; its sp. gr., about 0·998 at 14½° (58° F.). It forms a perfect solution of acid reaction with chloroform, benzol, ether, and warm amylic alcohol; the mixture with carbon bisulphide is turbid; it dissolves partially in glacial acetic acid, acetone, and absolute alcohol, leaving, after boiling and cooling, a considerable amorphous residue. This latter character distinguishes it from rosin and Venice turpentine, which are completely dissolved by these menstrua, and even by spirit of wine containing 70–75 per cent. of alcohol. Its composition varies greatly within certain limits, but may be approximately stated as 24 per cent. of essential oil, 60 of resin soluble in boiling alcohol, and 16 of resin soluble in ether. Its medicinal properties resemble those of copaiba, but it is now almost obsolete in pharmacy. Its physical qualities render it valuable for mounting microscopic objects, and it is used for making varnish. It is obtained chiefly in Lower Canada, and shipped from Montreal and Quebec, in kegs and casks. The annual crop varies from 2000 to 7000 gal. The approximate London market value is 8*d.* a lb.

3. *Carpathian balsam* (Fr., *Térébinthine des Carpathes*).—This turpentine is yielded by the Cembran, Siberian, or Swiss stone pine (*Pinus Cembra*), a tree forming the last zone of forestal vegetation, and occurring in France only on the Briançonnais Alps. The bark contains reservoirs of a liquid, colourless, limpid oleo-resin, having a pleasant odour, and acrid bitter flavour. It is rare in commerce.

4. *Chian or Cyprian turpentine* (Fr., *Térébinthine* [*Baume*] *de Chio* [*Chypres*]; Ger., *Chios, Cyprischer Terpentin*).—This is a product of *Pistachia Terebinthus*, a shrub or tree of the Mediterranean islands and shores and Asia Minor, extending as *P. palæstina* to Syria and Palestine, as *P. cabulica* eastward to Afghanistan and Beluchistan, and as *P. atlantica* to N. Africa and the Canaries. The commercial source of the oleo-resin is at present exclusively the island of Chios (Scio), but the wide distribution of the plant would facilitate the increase of the supply if necessary. In the Algerian forests, it is abundant as a large tree (50 ft. high and 6 ft. circ.), and affords a spontaneous exudation during the hot weather amounting to 7–14 oz. This spontaneous exudation is considered superior to that which is induced by incising or puncturing the bark, but is much less plentiful. Chios supplies the world's needs of this turpentine from about 1000 trees, some being 800–900 years old. Longitudinal incisions are made in the lower portion of the stems about April, when the trees are in full bloom. These incisions are prolonged upwards more or less, according to the quantity of turpentine it is desired to obtain, the resinous juice being secreted in special cells in the bark. The incisions are renewed every year. The annual crop of Chios is about 300–400 *okes* (of 2·82 lb.), this being the quantity ordinarily demanded by the market; but in an exceptional case, probably 3000–4000 *okes* could be secured in one season. The flow from the incisions continues during the whole summer, and the quantity amounts to about 10–11 oz. A century ago, the turpentine was caught from the incisions in little earthenware cups suspended from the stems; but the low prices ruling in more recent years favoured carelessness in the collecting, and the common practice of the present day is to leave the exudation to harden on the stem, or fall upon the sand or stones beneath. Hence the impure and inferior character of the modern drug. It undergoes some purification locally by being melted in the sun and strained through small baskets. The trade is almost exclusively in the hands of the Jews.

The sole use of this turpentine in England is for medicinal purposes. It had long been virtually obsolete, when Dr. Clay's success in treating cancer with it recalled it into notice, and created a demand for it which was greater than could be immediately supplied, whence much sophistication and substitution were resorted to, the favourite materials apparently being Canadian and common turpentine. Its chief characteristics are as follows. The flavour is feebly aromatic and terebinthinous, quite devoid of bitterness and acridity. The odour is pleasantly aromatic, faintly terebinthinous, and quite characteristic; it has been likened to elemi and to fennel, and is very distinct from coniferous oleo-resins. The consistence varies greatly with age. The solubility of the drug in 1 vol. of warm rectified alcohol (60 o.p.) is almost complete; it is not quite bright, but does not deposit to any large extent on cooling. Many of the coniferous resins may thus be detected. Organic remains are always present in Chian turpentine, from the method of collection; these may be studied as additional evidence of the origin of the drug under examination.

5. *Common* [*American and Bordeaux*] *Turpentine* (Fr., *Térébinthine commune*; Ger., *Gemeiner Terpentin*).—Common turpentine is afforded by a number of species of pine in both hemispheres. In Europe, they are chiefly the Scotch pine (*Pinus sylvestris*) in Finland and Russia; the Corsican pine (*P. Laricio*) in Austria and Corsica; the maritime fir or *pin maritime* (*P. Pinaster* [*maritima*]) in S.-W. France. In Asia, there are *P. excelsa* in Nepal and the Himálayas, *P. longifolia* in the Himálayas, *P. Gerardiana* in the Himálayas, *P. Massoniana* in Japan and Burma, and *P. Khasyana* and *P. Latteri* in Burma. In America, the swamp or Georgia pitch pine (*P. australis* [*palustris*]) and the loblolly (*P. Tæda*) in the S. United States, and the common red pine (*P. resinosa*) in Canada. The cultivation of these trees will be described in the article on Timber. In the present article, attention will be confined to their resinous exudations.

The so-called "pine barrens" of the United States extend from Virginia to the Mexican Gulf, especially through N. and S. Carolina, Georgia, and Alabama, but the extraction of turpentine is an industry mainly developed in N. Carolina. In winter (November–March), the "boxing" is carried on. This consists in cutting cavities in the tree, at 6–12 in. above the ground, and shaped like a distended waistcoat-pocket, the lower lip being cut horizontally, the upper one arched, and the bottom of the box being about 4 in. below the former, and 8–10 in. below the latter. The capacity of each "box" is about 2–3 pints, and its purpose is to form a receptacle for the exudation. The boxes are cut by means of a specially-shaped axe, and considerable skill is required to wield it properly, a chief object being to attain the desired capacity while approaching as little as possible the heart of the tree, and thereby endangering its life. An expert may make a box in 10 minutes, or about 50–60 in a day. The box being made and carefully cleaned of all chips, the exudation is induced by removing with the axe a thin slice from the upper lip of the box, including the bark and about 2 or 3 rings of the wood. There are commonly 3 boxes in a tree of 18 in. diam., it being a good rule to have at least 6 in. of face between the boxes. Some authorities are of opinion that it is beneficial to restrict operations to the northern face of the tree, the turpentine thereby retaining more of the volatile constituent, and the boxes being less exposed to the dust and leaves blown about by the southerly winds of summer. From the pared upper lip of the box, the sap begins to flow about the middle of March. From that time, the surface of the wound requires to be renewed every 7–10 days, which is effected by slicing off about $\frac{1}{8}$ in. from its face, the object being merely to expose fresh tissue as fast as it becomes clogged by the exudation. The latter mainly collects in the box, and is dipped out at intervals by special ladles, and barrelled. By the repeated slicing of the upper lip of the box, the wound ascends the tree to a height of 12–15 ft., ladders being used in the later years during which the operation is prolonged. The higher the wound has been carried, the greater the surface passed over by the exudation on its way to the box, and the greater the proportion which solidifies prematurely on the wound. This is the portion which is termed "scrape" in America (see Thus, p. 1684). The liquid portion which collects in the boxes is called "dip," in contradistinction. The scrape is removed about once a year; by allowing it to accumulate excessively, the yield of dip is much reduced. The 1st year's flow of a newly-boxed tree is known as "virgin dip," and is separately barrelled, being of superior quality. All leaves and chips should be cleared away from around the base of the trees, to avoid the outbreak of fire, and afford no harbour for insects.

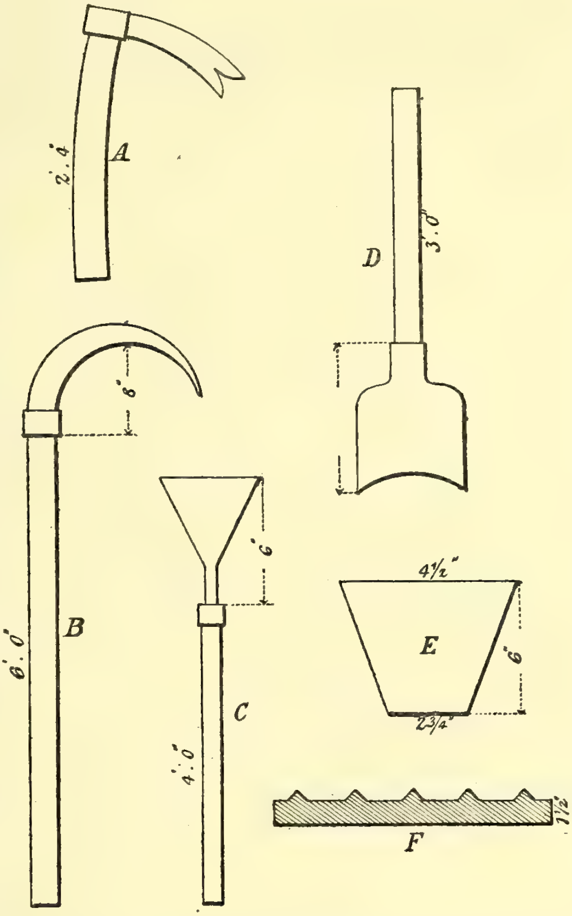
The crude turpentine has to undergo a process of distillation, to separate the "rosin" from the "spirit," "oil," or "essence" of turpentine. This distillation is carried on mainly on the streams near the localities of production. During the Civil War, large quantities of the crude oleo-resin were shipped to England for distillation, but this has long since ceased to be the case. The little sent into the N. States undistilled is used for making printing-ink. The production in the United States in 1876 was stated at 300,000 casks turpentine-spirit, and 1,500,000 barrels (of 280 lb.) of rosin.

Both rosin and turpentine-spirit were made in Canada, during the American Civil War, from the common red pine (*Pinus resinosa*), which grows abundantly in the N. counties of Ontario. The turpentine obtained from it is not identical in its qualities with that of the S. States, but forms a convenient substitute. Since the supplies of the southern article have resumed their normal condition, this manufacture has been abandoned.

In the French departments of Landes and Gironde, the extraction (*gemmage*) of the crude oleo-resin is conducted in a much more rational manner. Towards the end of February or beginning of March, preparations are commenced by thinning down the rough bark till only the last cortical layers remain covering the sap-wood, thus presenting a smooth even surface. The thinning is confined to the space which will be operated on during the current season, allowing a margin of 4 in. in height and $\frac{3}{4}$–$1\frac{1}{4}$ in. in width, so as to prevent bark fragments from falling into the receptacle placed to catch the exudation, and avoid the blunting of the edge of the instrument used in making the incision. The next operation, generally performed about 1st–10th March, consists in cutting the resiniferous ducts by means of the *abchotte*. The workman cuts into the foot of the tree an incision with a convex top, termed a *carre*, measuring 4 in. wide, $1\frac{1}{4}$ in. high, and $\frac{1}{2}$ in. deep. The crude turpentine (*gemme*) escapes in viscous transparent drops, thickening by exposure to the air, a portion adhering to the *carre*, while the more liquid remainder flows into a receptacle. This latter was formerly a hole made in the earth at the foot of the tree, and named *crot*; but since 1860, little earthenware dishes have come into general use, the oleo-resin being conducted into them by strips of zinc, called *crampons*. The renewal of the wound (*piquage*) is performed every 5–7 days. When the dishes are sufficiently full, their contents are emptied into a wooden basket termed an *escouarte*, the dishes are replaced, and the oleo-resin is conveyed to large reservoirs known as *barcous*, built of wood or bricks here and there in the forest, where it remains till required for manufacture. By the *piquage*, the *carre* constantly increases in height, but never exceeds certain dimensions. These have been recently fixed at the following figures:—Height: 1st year, 22 in.; 2nd, 51 in.; 3rd, 80 in.; 4th, 109 in.; 5th, 148 in.; width, $3\frac{1}{2}$ in.; depth, $\frac{1}{2}$ in., measured from a line parallel with the red part of the bark.

There are two modes of *gemmage*: *à mort* and *à vie*. The former is applied only to trees which are to be felled, in which case, it is desired to extract the greatest possible quantity of turpentine in the shortest time, and with this object, a number (2–6) *carres* are made simultaneously. The latter system (*à vie*) is adopted with trees which are to remain growing (called *pins de place*), and in which never more than one *carre* is opened at a time. When the first, at the end of 5 years, has a height of 148 in., the tree is allowed to rest for several years; a fresh one may then be made at a distance of not less than 6–8 in. from the last. The old-fashioned plan of collecting the turpentine in a hole in the ground is termed *gemmage au crot*; the modern plan of using earthenware dishes is known as the *système Hugues*. By the latter, the yield is increased $\frac{1}{3}$, and the value 10 *francs* (8*s.*) a barrel, while the additional cost is about 5*c.* (2½*d.*) a tree per annum. The *gemmage à mort*, on trees which are to be felled, is performed as soon as they are large enough to support a *carre*, which is when they are 16 in. round, usually attained at an age of 20 years. Until 1877, in the government forests, the *gemmage à vie* was commenced on reserved timber at a circumference of 39 in., but this has since been increased to 43 in., when the pines are 30–35 years old. The mean annual yield per *hectare* (of 2½ acres) of turpentine and "thus" varies from 240 *kilo.* (of 2·2 lb.) in the younger forests, to 450 *kilo.* in those where the trees are mostly 40–70 years of age. The yield, however, fluctuates greatly both in quality and quantity, according to the season and other varying conditions.

1183.

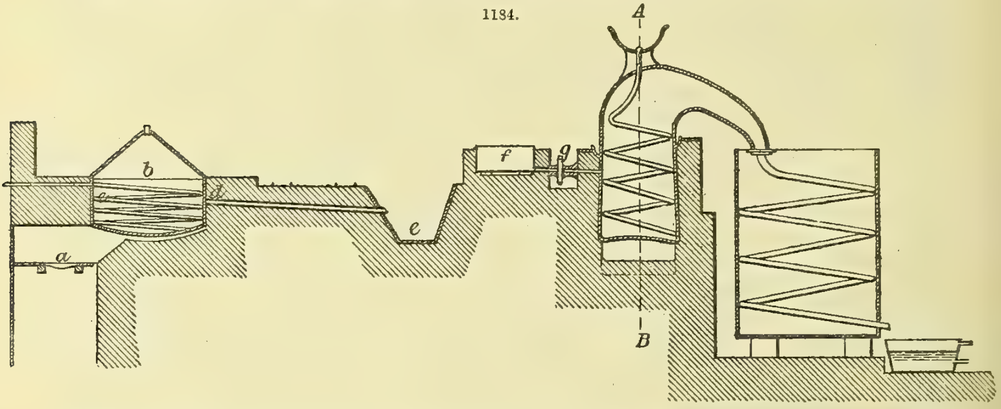


The tools employed by the *résiniers* or collectors are shown in Fig. 1183. The *abchotte* or *abchot* A is a sort of axe, used to make the *carres* and to renew the wound. The *barrasquite* B has a sharp, narrow, curved blade, while the *pousse* C is broad and straight; these two implements are employed in detaching the *barras* and *galipot* (see Thus), as well as in the barking operation, the *barrasquite* being adapted for use only at an inclination, and not above a height of about 8 ft. The *pelle* serves for barking the lower part of the tree, for constructing and cleaning the *crots*, according to the old mode of *gemmage*, and for removing the oleo-resin therefrom to deposit it in the *escouarte*. The little glazed earthenware pot E receives the exudation, which latter is removed from it by a small iron spatula. The *crampon* F is a curved zinc blade armed with 5 teeth; it is driven into the *carre* to conduct the flow of oleo-resin to the receptacle.

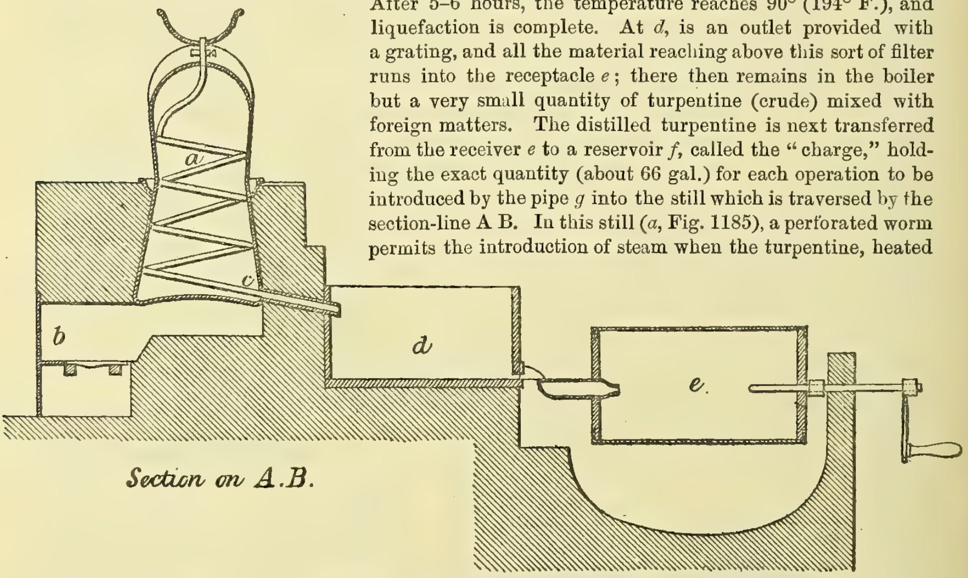
The *gemmage* of the *pin maritime* is almost confined to the basin of the Garonne. Attempts were made in Sarthe or Mayenne, and in Sologne, but unsatisfactory results caused their abandonment. The operation was formerly carried on on the Mediterranean shore, but has been given up in face of the enormous production of the Landes. It is recorded that the extraordinary cold of last winter (1880–1) killed nearly all the *pins maritimes* in N. and Central France, causing enormous losses, notably in Sologne. The occasion was seized by Prilleux to test the correctness of the popular belief that frost destroys the oleo-resin; the result of his investigation was that the dry wood of trees not killed by frost gave only 2–3 per cent. of resin, while those which were killed gave 3-4 per cent. This probably signifies that the dead tissue was not capable of retaining any of the oleo-resin, rather than that the frost actually augmented the secretion. About 600,000 *hectares* of this pine now exist in the Landes and on the sand-dunes. The annual exports now amount to the following figures:—To Belgium, England, and Germany, 3 million *fr.* worth of turpentine-spirit; to Germany and England, 2½ million *fr.* worth of distillation residues (rosin, pitch); finally, to Germany, England, and Holland, ½ million *fr.* worth of thus, tar, &c. The consumption in France is estimated at 9 million *fr.* The total harvest in 1874 was 29,395,417 *kilo.* (of 2·2 lb.).

Many improvements in the distillation of the crude oleo-resin and its products have of late years been introduced in France. The arrangement of the apparatus for the first distillation, the separation of the rosin and the spirit of turpentine, is shown in longitudinal section in Fig. 1184, and in cross section on the line A B in Fig. 1185. The crude oleo-resin, after a certain amount of mechanical purification by straining and settling, is placed in the boiler *b*, fitted with a movable lid, heated by the fire *a*, and furnished with a steam-coil *c*. After 5–6 hours, the temperature reaches 90° (194° F.), and liquefaction is complete. At *d*, is an outlet provided with a grating, and all the material reaching above this sort of filter runs into the receptacle *e*; there then remains in the boiler but a very small quantity of turpentine (crude) mixed with foreign matters. The distilled turpentine is next transferred from the receiver *e* to a reservoir *f*, called the "charge," holding the exact quantity (about 66 gal.) for each operation to be introduced by the pipe *g* into the still which is traversed by the section-line A B. In this still (*a*, Fig. 1185), a perforated worm permits the introduction of steam when the turpentine, heated by the fire *b*, has attained a temperature of 135° (275° F.). Effervescence ensues, and the "spirit" or "essence" separates completely. At *c*, is an opening closed by a wooden bung, and carefully luted. When the spirit ceases to pass into the serpentine receiver (*h*, Fig. 1184), the operation is suspended; the rosin, at a temperature of about 130° (266° F.), escapes at *c* into a box *d*, and thence into a cylinder *e* formed of very fine metallic gauze. This cylinder is made to revolve on its axis; the rosin falls through into a receptacle, while an unimportant residue remains inside. The rosin may be at once barrelled and shipped. The spirit leaving the serpentine cooler (*h*, Fig. 1184), being cloudy, is placed in large earthenware jars holding about 66 gal. and with clay-luted covers, recalling the *tinajas* used in the olive-oil industry (see p. 1403). Here it remains 4–5 days, and deposits the little remaining impurity. Copper vessels are sometimes substituted for these jars, and with advantage.

1184.



1185.



Section on A.B.

In some works, a few improvements have been made in the foregoing processes. The boiler *b* (Fig. 1184) may be fitted with an agitator, thus preventing solid matters from burning on to the bottom. Its cover may carry rims for containing water to condense the vapours. Thermometers may be placed in the boiler and still for regulating the temperature. Finally, it has been attempted to employ steam-heat throughout, as being more easily controlled.

The treatment of the residues is described under Pitch, Rosin, and Tar (pp. 1678–81, 1683–4).

The crude turpentine commonly reaches the works in barrels containing about 50½ gal., and weighing about 517 lb. The yield from this by the oldest method was only 33 lb. of turpentine-spirit, which was increased to 83 lb. by using hot water in the still of Fig. 1185, while by the adoption of steam, the result is 99 lb. of turpentine-spirit, and about 352 lb. of dry matters. The steam process not only effects a greater yield, but produces a better article, and requires less time and labour.

The Russian method of tapping differs essentially from both the American and the French. The trees, when 20 ft. high below the branches and 3½–7 in. thick, are stripped of a piece of bark about 28 in. wide, and leaving only about 2–3 in. of the trunk undenuded, preferably on the north side. The oleo-resin exudes and becomes inspissated on the barked patch (really forming "thus"), and is scraped off in the following autumn, averaging about 14 oz. to a tree. Next year, the barking is continued in narrow rings for a distance not exceeding 16 in., and the product may amount to 21 oz. In the 3rd year, it reaches about the same figure; in the 4th, it falls back to 14 oz. In the 5th year, 24 in. are removed, but the yield is then small; the barking is stopped in the 6th year, but the tree is left standing for 3–4 years, becoming saturated with oleo-resin, and thus of increased value for the tar-oven (see Tar, p. 1683).

The Indian conifers already named are capable of affording considerable quantities of turpentine, probably at a price which would be remunerative in local markets, but not for export in competition with the American article.

Common turpentine is a honey-like liquid, of strong, disagreeable, characteristic odour, and acrid, bitter, nauseous flavour; it is soluble in alcohol, ether, carbon bisulphide, and fixed and volatile oils. The drying propensity varies, being strongest in the Bordeaux kind. By aqueous distillation, the common turpentines yield 15–30 per cent. of essential oil (see Vegetable Volatile Oils, p. 1431). The consumption of common turpentine in the preparation of varnishes and paints is very extensive. The approximate London market value of American turpentine in casks is 20–30*s.* a cwt.

Turpentine is very rarely exported in its crude state, but the commerce in turpentine-oil (called also "spirit" and "essence") has considerable importance. Our imports were 236,026 cwt., value 271,618*l.*, in 1876; 324,145 cwt., 358,000*l.*, in 1878; and 271,699 cwt., 378,838*l.*, in 1880. Of the last-mentioned, the United States contributed 261,911 cwt., 365,752*l.* Our re-exports in 1880 were 5715 cwt., 8319*l.*, to France; 5531 cwt., 6231*l.*, to Belgium; 4404 cwt., 6640*l.*, to Holland; 8203 cwt., 12,742*l.*, to other countries. Our imports from the United States rose from 228,429 cwt. in 1876, to 322,251 in 1878, but receded to 261,911 in 1880. The American port of Boston received 217 bar. crude turpentine and 6546 bar. turpentine-spirit in 1880, and exported 730 bar. of the latter. New York exported 135 bar. crude turpentine in 1878, and 58 in 1879; and 17,243 bar. turpentine-spirit in 1878 and 5824 in 1879; of the spirit shipped in 1878, 4814 bar. came to Great Britain, 2023 bar. went to N. Europe, 1238 bar. to other Europe, 9107 bar. to S. America, the E. and W. Indies, &c. Wilmington, in 1878, sent 11,024 bar. spirit coastwise, and exported 107,152 bar., total value, 266,927*l.*; and of crude, 3087 bar. coastwise and 1449 abroad, total value 1844*l.* Savannah, in 1879, exported 512,268 gal. turpentine, of which, 274,717 gal. came to British ports; in 1880, the figures were 21,743 bar. spirit coastwise, and 605,412 gal. exported. Mobile, in 1880, sent 25,109 bar., value 73,240*l.*, to the interior of the United States. The Greek port of Syra, in 1877, sent 112*l.* worth of turpentine to Egypt, 112*l.* to Turkey, and 107*l.* to Great Britain.

6. *Hungarian balsam* (Fr., *Térébinthine d'Hongrie*).—The dwarf or mountain pine (*Pinus Pumilio*) yields a pale-yellow clear liquid, of herbaceous odour and piquant flavour, still known under the name of Hungarian balsam, but hardly met with now in commerce. Its essential oil is used as an inhalation in throat-diseases.

7. *Strassburg turpentine* (Fr., *Térébinthine d'Alsace, de Strasbourg, du sapin,* or *au citron*; Ger., *Strassburger Terpentin*).—This oleo-resin is afforded by *Pinus Picea* [*Abies pectinata*], the silver fir, whose geographical distribution is recorded under Timber. The secretion of the oleo-resin is analogous to that of Canadian turpentine, and its collection is effected in a precisely similar manner. It is afterwards filtered through bark funnels. In all respects, it bears a close resemblance to Canadian turpentine, except in wanting the acrid bitterish flavour of the latter, and any distinct fluorescence. It possesses the properties of common turpentine, with the advantage of a very pleasant odour. It was formerly held in great medicinal esteem, but is now nearly obsolete, and is collected only in very small quantity near Mutzig and Barr, in the Vosges.

8. *Venice or Larch turpentine* (Fr., *Térébinthine de Venise, de Briançon, du mélèze, Suisse*; Ger.,

Venetianischer, Lärchen Terpentin).—This variety of turpentine is obtained from *Pinus Larix* [*Larix europæa*], the European larch (see Timber). The collection of the oleo-resin is carried on chiefly about Mals, Meran, Botzen, and Trent, in the Tyrol; occasionally and in trifling quantity in the Valais, Piedmont, and some places in France. The resiniferous canals of this species are situated mainly in the sap-wood, hence a special mode of extraction is necessary. This consists in cutting a hole to the centre of the tree, at about 1 ft. above ground, in the spring of the year; this is plugged up till the autumn of the same or the following year, when it is opened, and the accumulated oleo-resin is removed in an iron spoon. The yield thus amounts to about ½ lb. yearly, without appreciable damage to the tree. Formerly, in the Piedmontese and French Alps, a number of wide cavities were made, and left open; the product in this case reaches 8 lb. annually, but the timber is greatly injured, and the tree soon ceases to yield at all. It is further urged in support of the modern plugging process that it tends to maintain the transparency and purity of the turpentine.

Venice turpentine is less siccative than any other kind. It is a slightly turbid, translucent, pale-yellow, thick liquid, of less pronounced odour than common turpentine, and an acrid, bitter, aromatic flavour. It has no special medicinal qualities, and is scarcely known now in English dispensing, though useful for plaisters. It is often prescribed in veterinary practice, but is then generally replaced by an artificial compound of rosin and turpentine-oil, the true article being absorbed by the Continental markets.

Varnishes [Natural].—This term is applied to a group of products resembling the well-known Burmese lacquer. The chief kinds to be described are (1) Burmese, (2) Cingalese and Indian, (3) Japanese and Chinese.

1. *Burmese.*—The *thit-tsi* of the Burmese is a thick, viscid, greyish, terebinthinous fluid, soon assuming a black colour on exposure to the air. It is contained in every part of the tree called *Melanorrhœa usitatissima,* a native of Burma, and extending to the N.-E. frontier of Silhet and Tippera, and identical with the *kheu* tree of that district. The geographical range may be stated as lying between Munipur (25° N. lat., 94° E. long.) and Tavoy (14° N. lat., 97° E. long). The tree attains its greatest size in the valley of Kubbu, and becomes smaller as it approaches the sea on the Tenasserim coast, where it frequents comparatively low situations. The extraction of the varnish is performed in the following simple manner. Short joints of a thin kind of bamboo, sharpened to a pen-like point at one end, and closed at the other, are thrust slantwise into wounds in the bark of the stem and main boughs, and left for 24–48 hours; on removal, their contents, rarely more than ¼ oz., are emptied into a rattan or bamboo basket previously varnished over. The collecting season lasts while the leaves are off the trees, or from January till April; the bamboos are renewed as often as the juice requires, and are sometimes inserted to the number of 100 in a single tree. A good tree will produce 1½–4 *viss* (of 3½ lb.) annually. At Prome, the pure article fetches about 2*s.* 6*d.* a *viss.* It is commonly adulterated with gingelly-oil. It dissolves in alcohol, turpentine-spirit, and benzol, assuming greater fluidity. It may be diluted with gold-size, which tends to hasten its drying and intensify its colour, while turpentine renders it browner. Locally it is used in enormous quantities in lacquering furniture, temples, idols, varnishing vessels for holding liquids, and paying river-craft. The very long time it occupies in drying has given rise to unfavourable reports on it in European industry.

2. *Cingalese and Indian.*—The black varnish of Ceylon is derived from a species of *Semecarpus*, and similar products are obtained in India from *S. Anacardium* in the Concans, Coromandel, Courtallum, Guzerat, Bengal, and Travancore, from *S. travancorica* in the moist forests of the Tinnevelly and Travancore mountains, and from *Holigarna longifolia,* a common tree about the W. ghats of the Madras presidency, and occurring in Bombay and Bengal. The juice exudes from natural fissures in the bark of the latter, and from the pericarp of the three former, hardening, and assuming a black colour. It forms an excellent varnish, adhering strongly to wood and metal. It is also used as a marking-ink, much the same as the juice of the W. Indian *Anacardium occidentale,* or cashew-nut (see Nuts, p. 1352).

3. *Japanese and Chinese.*—The natural varnish of Japan and China is derived from several species of *Rhus,* whose fruits afford the Japan wax of commerce (see Wax). The stems of the trees are incised at the age of 4–5 years, and the productiveness only lasts for 3 years. The implement used is a sort of double hook called *kaki gama*; with it, a horizontal gash is first made in the bark, then an incision in the centre of the gash. The exudation is collected on an iron spatula, and poured into a vessel suspended from the collector's waist. The incisions are continued upwards till the whole tree has been wounded; it is then cut down, the branches are lopped off, soaked in water for 10–20 days, and abundantly incised. The product is most extensively employed in Japanese and Chinese lacquer-work.

Wood-apple (Ger., *Feroniagummi*).—An arabic-like gum of some industrial importance is afforded by the wood-apple tree (*Feronia elephantum*), an Indian tree, found in Coromandel, the W. coast, Guzerat, and probably Travancore and Burma. The gum is used by dyers, and by painters in miniature and on chintz; it is also employed in making ink and some varnishes, and in preparing fine whitewash. It affords with water a brownish tasteless mucilage, not less adhesive than that of gum arabic. For preparing water-colours, it has a reputation beyond all other gums. It is much cheaper than gum arabic, while apparently equal to it for all purposes.

Xanthorrhœa, Botany Bay, Black-boy, Grass-tree, or Akaroid resin, or Ground-shellac.—These names have been applied at various times to the resins afforded by the *Xanthorrhœas*, of which over half a dozen species have been identified, all indigenous to Australia. In W. Australia, these plants form a principal feature in the vegetation. In Gippsland and the Western Port district of Victoria, *X. australis* abounds on morassy and sandy heaths. All species contain a large quantity of resin, which exudes naturally in such a degree as to cover the base of the leaves and the subterranean portions of the plant, while by crushing the woody stems and sifting or washing away the chips, some 50–60 lb. of the resin may be got from a single specimen. It is usual to distinguish the resins as "red" and "yellow." The former is ascribed by Wiesner exclusively to *X. australis*, and the latter to *X. hastilis*; while *X. arborea* is accredited with the production of both kinds of resin, the fact probably being that it gives a yellow resin becoming superficially red by age. On this point, there is much difference of opinion. All kinds are completely soluble in alcohol, and have a pleasant benzoin-like odour. They have been employed in the manufacture of spirit- and other varnishes, especially for application to metals. Their lime and soda soaps are used in sizing paper. They may also be availed of for the manufacture of picric acid, and an illuminating-gas much cheaper (locally) than coal-gas. The yellow kind is used for staining wood in imitation of cedar. It is said that it can be produced at a cost not exceeding 6*l.* a ton, while possessing a value of 30*l.* a ton in Melbourne for varnish-making purposes.

Miscellaneous.—Besides the foregoing important products, the following species may be recorded as capable of yielding resinous or gummy substances:—

Adenanthera pavonina, in Ceylon, the Peninsula, Travancore, Silhet, and Assam: a gum.

Ægle Marmelos (see Drugs—Bael, p. 793): an amber-coloured gum in small tears, which has been styled as a "good arabic."

Agati grandiflora, in Travancore: a kino-like exudation.

Ailantus excelsa, in the N. Circars and Coimbatore: a gum resembling moringa, only partially soluble.

Ailantus malabarica, in Travancore and Malabar: a dark-brown, homogeneous, soft gum-resin, of fragrant odour, sometimes burnt as incense.

Artocarpus incisa, in Ceylon: a gum or resin called *ratadel.*

Azadirachta indica, in the Peninsula and Assam: said to form a portion of E. India gum (arabic).

Bassia spp. (see Oils, pp. 1392, 1394, 1408, 1410): white milky gums from deep incisions around the trees, but quite useless commercially.

Bauhinia spp. (see Fibrous Substances, p. 921): brownish, mild, cherry-like gums.

Borassus flabelliformis (see Fibrous Substances, pp. 932–3): a black gum.

Calyptranthes caryophyllifolia, in the Peninsula and N. India: "navel-tree" gum, or a kino-like substance.

Careya arborea, in the Peninsula, Concans, and Travancore: a greenish gum.

Cassia spp. (see Drugs, p. 798, Spices): a dark-coloured soluble gum, and from *C. auriculata* an esteemed medicinal resin.

Cedrela Toona, at the foot of the Himálayas: a gum or resin.

Celtis orientalis, in Coromandel, Bengal, and Travancore: a gum resembling cherry.

Ceradia furcata, in S.-W. Africa: a myrrh-like gum-resin (see p. 1625).

Chickrassia tabularis, in the Cunnawady Hills (India): transparent, amber-coloured gum.

Chrysophyllum ramiflorum, the *oaca* or *guariba* of Brazil.

Clusia spp., in Tropical America: chiefly *C. insignis* (a medicinal resin from the flowers), *C. alba*, *C. rosea*, and *C. flava* (pitch-like resins from the stems), *C. Galactodendron* (a *palo-de-vaca* or "cow-tree"), *C. Duca* (*duca* resin, used as incense), *C. Calaba* (a copal resin called *aceite de Maria*).

Cordia Rothii, in Mysore: a gum.

Cycas circinalis, in the S. Concans: a tragacanth-like gum.

Elate sylvestris, common throughout India: a glossy, dark-brown, flexible gum.

Emblica officinalis, common in most parts of India: a brittle gum in stalactitic pieces.

Eriodendron anfractuosum (see Fibrous Substances, p. 948): a vinous-red, semi-soluble gum, resembling moringa.

Erythrina indica, in Coromandel, the Concans, and Assam: a dark-brown opaque gum of no promise.

Garuga pinnata, in Coromandel, Assam, and N. India: an inferior gum called *curvamboo.*

Grevillea robusta, in Australia: a vinous-red, semi-soluble gum resembling moringa.

Grislea tomentosa, in the Peninsula, Concans, W. Ghats, and N. India: a white kuteera-like gum, used in dyeing.

Gyrocarpus Jacquinii, in Coromandel: a black tar-like gum called *poongallee.*

Heritiera littoralis, in Ceylon: a gum or resin called *mendora.*

Jatropha Curcas, in Coromandel and Travancore: a gum.

Lucuma spp., in Brazil: *L. gigantea* (the *jaqua*), *L. fissilis* (the *guaracua*), *L. lasiocarpa* (the *abiarana*), *L. laurifolia* (the *guapeba vermelha*), *L. procera* (the *maçaranduba blanca*).

Macaranga spp., in Malabar and Travancore: a pure light-crimson gum, used for taking impressions.

Melia Azedarach, in N. India, the Deccan, and Concans: a tasteless, soluble gum, resembling wood-apple.

Melia sempervirens, in W. Indies: a gum of small importance.

Mesua ferrea (see Dyestuffs—Nagkassar, p. 864, Perfumes—Nagkassar, p. 1526): an oleo-resin that might replace Canadian turpentine.

Michelia Champaca (see Oils—Ilang-ilang, p. 1422): a gum.

Mimusops Elengi, in the Circars, W. Ghats, the Peninsula, and Silhet: the *pogada* gum of Madras.

Nerium suaveolens, in Madras: a dull-red gum.

Opuntia rubescens, in Brazil: a kuteera-like gum.

Panax Colensoi, in New Zealand: an arabic-like gum, occasionally used for adhesive purposes.

Pittosporum spp., in New Zealand: a gum-resin in very small quantity.

Podocarpus cupressina, in Java: a resin (see p. 1625).

Poinciana elata, in Coromandel, Malabar, Guzerat, and Arcot: a gum.

Poinciana regia, in Madagascar: abundance of gum.

Pongamia glabra, in Coromandel, Concans, Deccan, Patna, and Assam: a thick, black, opaque gum.

Prosopis spicigera, in Coromandel: a gum resembling mezquite.

Punica granatum, in Barbary: "pomegranate-gum."

Sapindus spp. (see Nuts—Soap-nut, p. 1360): a gum.

Soymida febrifuga, in Central and S. Provinces and Guzerat: a tolerable gum.

Spondias mangifera, in the Peninsula and Upper India: a mild, insipid, arabic-like gum.

Stereospermum suaveolens, in the Deccan, Bengal, and W. coast: a moringa-like gum.

Tamarindus indica (see Fruit—Tamarinds, p. 1028): a black gum.

Tamarix dioica, from Sind to Assam and Burma: a friable, soluble, pale-yellow gum.

Terminalia spp. (see Oils—Myrobalan, p. 1396, Tannin—Myrobalans): abundance of transparent soluble gum resembling arabic; best and most from *T. belerica.*

Thespesia spp. (see Fibrous Substances, p. 998): a dark, tasteless, cherry-like gum.

Vachellia Farnesiana, in Bengal, Assam, and the Peninsula: an abundance of arabic-like gum.

Wrightia spp., in Ceylon and S. India: gums used for ordinary purposes.

Zizyphus flexuosa, in Nepal: *simli* gum, resembling inferior arabic.

Commerce in Unenumerated Gums and Resins.—Our imports of unenumerated gums and resins were 74,077 cwt., 264,995*l.*, in 1876; 86,972 cwt., 274,577*l.*, in 1877; 76,152 cwt., 301,858*l.*, in 1878; 82,327 cwt., 344,410*l.*, in 1879; 92,283 cwt., 345,087*l.*, in 1880. The figures for 1880 were made up as follows:—Straits Settlements, 19,225 cwt., 76,721*l.*; Bombay and Sind, 18,364 cwt., 54,073*l.*; British W. Africa, 7750 cwt., 26,078*l.*; Egypt, 7309 cwt., 19,450*l.*; Holland, 6303 cwt., 16,035*l.*; France, 5304 cwt., 17,960*l.*; Turkey, 5258 cwt., 44,420*l.*; Morocco, 5226 cwt., 19,044*l.*; Aden, 4824 cwt., 19,072*l.*; other countries, 12,720 cwt., 52,234*l.* Our exports of unenumerated gums in 1880 were:—17,251 cwt., 83,608*l.*, to United States; 11,830 cwt., 38,647*l.*, Russia; 11,025 cwt., 38,823*l.*, Holland; 8530 cwt., 31,188*l.*, Germany; 4740 cwt., 22,509*l.*, France; 3432 cwt., 10,724*l.*, Belgium; 9888 cwt., 27,823*l.*, other countries; total, 66,696 cwt., 253,322*l.* The imports of unenumerated gums from Portugal were 572 cwt. in 1876, 350 in 1878, 420 in 1880. From Portuguese W. Africa: 516 cwt. in 1876, 3 in 1879, 163 in 1880. From the Philippines: 373 cwt. in 1877, 1766 in 1880. From European Turkey: 773 cwt. in 1877, 1818 in 1878, 1007 in 1880. From Asiatic Turkey: 4532 cwt. in 1876, 13,035 in 1878, 4890 in 1880; Musyna, in 1879, sent 25 tons, value 2750*l.*, to France, and 168 tons, 17,800*l.*, to Turkish ports; Aleppo, in 1880, sent 18 tons, 2880*l.*, to England, 8 tons, 1280*l.*, to France, 2 tons, 320*l.*, to Italy, 4 tons, 640*l.*, to Austria, 8 tons, 640*l.*, to Turkey, 15 tons, 1200*l.*, to Egypt; total, 55 tons, 6960*l.*; Samsoon exported 774 cwt., 6192*l.*, in 1880; Adana exported 1820 bales, 12,487*l.*, in 1878. From Egypt (excluding "arabic"): 3889 cwt. in 1877, 8072 in 1879, 7309 in 1880. From Morocco (excluding "arabic"): 8168 cwt. in 1876, 3763 in 1879, 5231 in 1880; the exports from Mogador in 1880 (including arabic, euphorbium, and sandarach) were:—1427 casks, 12,725*l.*, to Great Britain; 140 casks, 1185*l.*, to France; 10 casks, 70*l.*, to Portugal; 1 cask, 8*l.*, to Spain; total, 4115 *quintals.* From W. Africa: 2911 cwt. in 1876, 629 in 1878, 773 in 1880. From E. Africa: 1181 cwt. in 1876, 381 in 1877, 966 in 1880. From Persia: 639 cwt. in 1876, 2469 in 1877, 362 in 1880; Bushire, in 1879, sent 1200 *rupees*' worth of "Persian gum" to England, and Bahrein sent 50 *rupees*' worth to Koweit, Bussora, and Bagdad. From British W.

Africa: 5675 cwt. in 1476, 4134 in 1878, 7547 in 1880. From Aden: 5001 cwt. in 1877, 9841 in 1880. From Bombay: 16,693 cwt. in 1876, 27,866 in 1877, 19,862 in 1880. From the Straits Settlements (excluding guttapercha and lac): 9832 cwt. in 1877, 7567 in 1879, 19,225 in 1880. From S. Australia: 373 cwt. in 1876, 4442 in 1879, 3908 in 1880. Panama exported 14*l.* worth of "balsam" to the United States in 1879.

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(See Indiarubber Manufactures; Oils [Vegetable Volatile]; Varnish; Wax.)

ROPE (Fr. *Cordage*; Ger., *Tauwerk*).

Of the industries dealing with fibrous materials, rope and twine manufacturing has been the latest to come under the influence of the mechanical inventor. Its comparative insignificance for a long time was its chief protection. Whilst the textile industries offered larger fields and greater rewards to the ingenuity of the schemer, this department was ignored. Rope and twine manufacturing as an industry was scattered all over this country in the towns and villages, but flourished mostly at or in close proximity to our sea-ports, where, for the supply of shipping, there existed the greatest demand for its products. As in every other handicraft, the processes until within a comparatively recent period, were of a rude and primitive character, having been transmitted from one generation to another through centuries, most probably without important modification. With the rise of the modern system of manufacturing, the growth of population, and the enormous development of commerce, our requirements were so largely increased that these primitive methods no longer sufficed to satisfy them. The inventor's aid was therefore called into requisition, and the result has been that, within the past 15–20 years, the ancient methods of manufacture have been quite revolutionized.

The raw materials employed in the manufacture of ropes, cords, and twine, are very various, and include hemp, flax, cotton, jute, manilla-hemp, coir, horse-hair, wool, camel-hair, and other animal fibres. In addition to these, iron, copper and brass-wire are sometimes employed, the first-mentioned metal having come into extensive use. In remote times in this country, the native rushes or *junci* were employed for making ropes, whence the word "junk," worn-out rope. To the preceding, the economical proclivities of the times have added the tows of the various fibres, scutching-waste, jute-cuttings, old ropes, refuse fibres, gunny-bags, sacking, and almost every description of waste from fibrous materials that can be combined by the twisting process into a yarn.

The highest qualities of the various articles are made from the best materials, such as the long line of the hemps and flaxes, and sound cotton. Medium sorts are produced from jute, various coarse fibres, and the tows of hemp and flax. Inferior descriptions are obtained from the wastes and broken-up materials just mentioned. Each of these leading divisions possesses numerous grades, accordingly as the materials employed will permit of being assorted into different qualities.

It is probable that, as the fibrous plants of different countries become better known, numerous additions will be made to the list, as it is certain that for these purposes, there are many quite as suitable as any now in use, almost unknown save to scientific inquirers. The qualities requisite are pliability, softness, smoothness, strength, and a length of staple of from 3 in. upwards.

The word "rope," properly used, implies an article exceeding 1 in. in circumference; smaller descriptions are named "cords," "lines," "twines," "threads," &c., and their constituents, "yarns." After the preparatory stages have been gone through, the product of the first operation, which is spinning, is "yarn." A given number of yarns—more or less, according to the thickness of the article required—are twisted together to form a "strand"; three of these combined by the same means compose a "rope"; whilst a similar union of three ropes constitutes a "cable."

In making cordage of all kinds, the object of twisting the fibres is to obtain increased length. Singular as it may appear, it has been affirmed, and probably with truth, that this twisting of the fibres does not increase the strength, but considerably diminishes it. If a given number of fibres of equal length be placed in parallel order, and their tensile strength be tested, it will be found considerably greater than that of the same fibres twisted into a compact cord. This is because, in the first case, the strain upon each fibre is equal to that upon every other, and the total strength is that of all of the fibres added together. When these fibres are twisted, those forming the external layer, having to wrap round those constituting the core, are strained both in this process and when their tensile power is tested, and are the first to break, thus leading to the fracture of each in detail. From experiments that have been made, it has been found that this loss of strength amounts to 30 per cent. of the strain-bearing power of the untwisted fibres. The object, therefore, being to get continuity of length, all twisting which exceeds that necessary to prevent the fibres slipping over each other when a strain is applied is to be avoided, as entailing a loss of strength.

Hemp (see Fibrous Substances, p. 934), the material of which the best ropes are ordinarily composed, as compared with flax, is much coarser and stronger, but is cultivated and treated in a very similar manner, the processes of retting, breaking, and hackling being like those of flax.

HAND-MADE CORDAGE.—In those establishments where the manufacture of ropes is still carried on by hand, the first operation is "hackling." A certain quantity of hemp is weighed to the hackler, and given proportions of this are combed out at one operation. The hackle or heckle consists of a number of steel pins vertically inserted in a board with their points upward. The fineness of these pins depends upon the character of the work. The operation of hackling differs little from that described in Linen Manufactures (p. 1244), detailing the treatment of flax. Each hackled portion is tied into a bundle, technically called a "strick of hemp." This is then passed to the spinner for making into yarn. The spinning process is conducted in a long covered walk, termed the "rope-walk," which is furnished with the simple means necessary for the conduct of the different operations. The principle end of this walk is usually called the "head" or "fore-end," and the opposite extremity, the "foot" or "back-end." At one end is a spinning-machine, consisting principally of a large wheel, which, by band, friction, or teeth (all are employed), drives a number of small pulleys or "whorls," each carrying a small hook on its axle, that, by the turning of the large wheel, receives a rapid rotary motion. A boy generally turns the wheel, and as many spinners can work from one wheel as there are small whorls driven by its revolution. The spinner, after fastening the strick of hemp round his body, draws out from the front of the bundle the quantity of fibres required to form the size or thickness of the yarn it is desired to make. Bending these fibres in the middle, he passes the bight upon the revolving hook, which instantly twists them, the spinner, at the same moment, beginning to walk backward, and passing more fibres to those which are already being twined. This is done continuously and carefully so as to maintain the evenness and continuity of the thread. In his right hand, the spinner carries a thick piece of woollen cloth, a portion of which he allows to fall over the fore-finger, and with which he grasps the fibres as they are drawn out, and presses them firmly between his two middle fingers. As he steps backward, the driving-wheel continuing its revolution, with his left hand he draws out and regulates the supply of fibre, so as to ensure the yarn being of equal thickness throughout its length. The "walk" may be 200 yd. upwards in length, and the spinner, as the yarn lengthens in his hands, passes it over bearers attached to pillars or the walls of the enclosure. When the length of yarn is completed, it is either passed to one side upon the bearers to await a finishing process, or is wound upon a reel and put aside until wanted.

If it is intended that the ropes shall be tarred, this process takes place at this stage. A number of yarns, 200–300, are laid together in parallel order, and passed through a boiler of hot tar. As they become saturated, the bundle of yarns is drawn through a hole, called a "grip," which has the effect of pressing the tar into the yarn, and removing the superfluous portion. Tarred ropes are more durable than untarred ones, owing to increased power of resisting the decomposing action of water in the alternate immersions or saturations and dryings to which ropes are often subjected in use.

The next operation is the "twisting" of the yarn, whether tarred or untarred, into strands. Rope-walks are usually divided into parts, each fitted with appropriate machinery: the spinning-walk, with its wheels, and the twisting- or laying-walk (sometimes combined in one, sometimes separate, according as the work may be light or heavy), each having its tackle-boards and sledges. At the head of the walk, two stout pieces of timber are inserted vertically in the ground. Across these, is bolted a strong board, which contains three holes corresponding to the number of strands in a rope. This forms the tackle-board. The three holes are in a horizontal line, and are for the reception of winches or forelock-hooks. The proper number of yarns to form the strand having been affixed to these hooks, the opposite extremities are attached to corresponding forelock-hooks in the breast-board of the sledge, a strongly-built frame of wood, constructed so as to be easily loaded with weights according to requirement, and furnished with twisting-hooks similar to those of the tackle-board. The sledge being drawn back, so as to bring the yarn into a tense condition, twisting is commenced both at the forelock-hooks and those of the sledge, the twist of course being in opposite directions. The contraction in length which ensues drags the sledge in towards the fore-end of the walk. When sufficient "hard," as twist is technically called, has been given to the strands, the twisting is complete. The three strands are then attached to the middle hook of the tackle-board, and each strand is laid into one of three grooves of a cone-shaped piece of wood, called a "top," and which will come under notice subsequently. These strands are next twisted together, the "top" receding from the twisting-hook as the rope is formed. This process is called "laying" or "first lay," and consists in combining three strands into a rope, the rope thus made being termed "hawser-laid." In this form, the strands are allotted a sufficient number of threads to give the required thickness to the rope. There is another combination, called the "shroud hawser-laid" rope, or "second lay," in which four strands are twisted round a core-piece placed in the centre to impart greater solidity to the rope. There is also the "third lay," or "cable-laid" rope, in which three ropes, as formed by the first-named process, are twisted or laid together to constitute a cable: a stout strong article formerly in extensive use for ship's purposes, but now mostly superseded by chain cables.

This brief description will sufficiently indicate the handicraft methods of rope-manufacturing, which are still in extensive use in many countries, but are in course of replacement by the introduction of machinery, which will now come under notice.

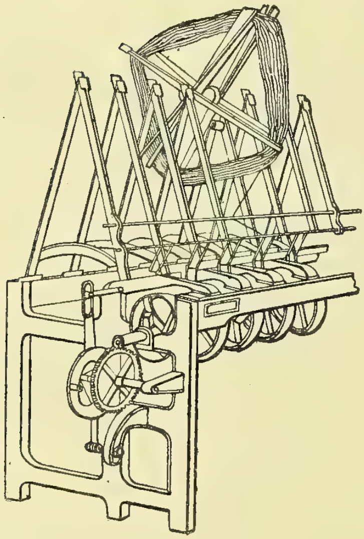
Machine-made Cordage.—The most complete rope- and twine-factories are fitted with every requisite for dealing with the raw material from the commencement, and carrying it through each succeeding stage until it emerges in the finished form, whatever may be required. This of course includes sets of preparatory and spinning machinery, which differ according to the nature of the material to be treated. The best descriptions of yarn are those made from the long fibre or "line" of the raw material, and the machinery employed is denominated "line-machinery," a set of which includes hackling-machines, spreading-frames, first, second, and third drawing-frames, roving-frames, and wet and dry spinning-machines. Every "set" of machines is subject to modification, according to the requirement of the manufacturer. Where a low quality of material is used, there are often only two drawing-frames in the set; but where good yarns are made, three are quite indispensable. For tow and low yarns from waste materials, what is called "tow-machinery" is employed, which, in several of its component parts, differs essentially from a line set.

The roughest and dirtiest qualities of material require some preliminary treatment, the first process being "willowing," to clear away the dirt and earthy matter that may have got intermixed with it. When the fibres are too long to be entrusted with safety to the carding-engine, the material is first passed through a "teazer," by which it is torn and broken down to the necessary dimensions. The teazer is called into requisition when such materials as jute, phormium fibre, some sorts of tow, long hemp which has been damaged, scutching-hemp, and some other sorts are used. Woven fabrics, such as old canvas, mats, and gunny-bags, are broken up by a "teazer-card," a combination of the foregoing, and a carding-engine.

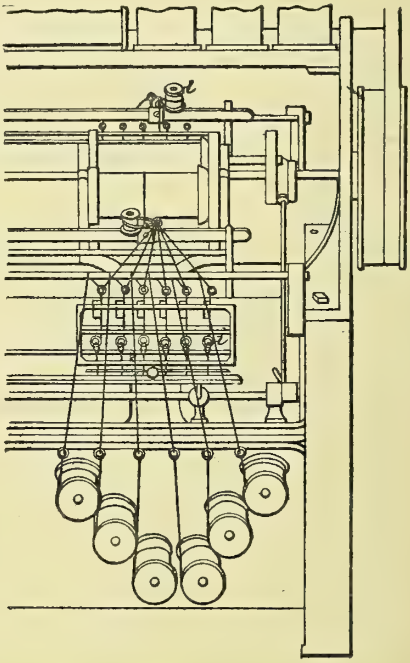
With an average quality of material, however, these processes are not necessary. It is at once passed successively through a "breaker" and "finisher" card, in which, the carding is completed, the fibres being laid parallel, and delivered in the form of a sliver. A number of these slivers are doubled in the drawing-frame, and attenuated or drawn down to the dimensions of one; this process is repeated in the second drawing-frame, by which it is sought to remove all irregularities. The sliver thus prepared is conveyed to the roving-frame, where further elongation takes place, and a slight amount of twist is imparted to the "rove," as it is called at this stage, in which it is also wound upon bobbins. The latter are then ready for the spinning-frame, in which the rove is further and finally attenuated to the required dimension, and firmly twisted, forming yarn. There are two methods of spinning, dry, and wet: in the latter, the water may be cold or hot, according to the nature of the work. The greater portion of spinning is dry, which enables a far more extensive production to be obtained, the cost of driving being less, and the outlay upon machinery much smaller. Ordinary yarns, and those for heavy twines, are spun on the dry system; fine yarns, on the wet plan with hot water, owing to the fact that hot water to some extent dissolves the natural gum which binds the fibres together, and thus liberating them, enables the yarn to be drawn out much finer, though the loss of its gum diminishes its strength. When it is desired to preserve the highest degree of strength, cold water is used. The coarsest yarns are often spun upon a modified roving frame, called the "Gill spinning frame," by which, one process is obviated, and the cost reduced. This spins coarse yarns, whether composed of line or tow materials.

Hand-spinning has so far been superseded by machinery that a great number of rope- and twine- manufacturers prefer to buy their yarns from spinners, who do not carry the processes farther. When this is the case, the yarn is received in the hank form, and is wound upon bobbins in a hank-winding frame, of which there are several kinds. The hanks are placed on a frame, and the end of the yarn is attached to a bobbin, which is driven by a drum, whose face revolves in contact with the barrel of the bobbin or the yarn upon it as it is filled (Fig. 1186). The machine has a transverse motion, by which the yarn is wound in even layers. These machines are made of various sizes, according to the fineness of the yarns, but average about 20 drums to a machine, which is thus enabled to wind from 20 hanks at once. These hank-winding machines are not required in establishments where the yarn is spun, as then the spinner is enabled to place his spinning-bobbins direct upon the creel of his twisting-frame, by which he saves two processes and two costs—reeling and re-winding.

1186.

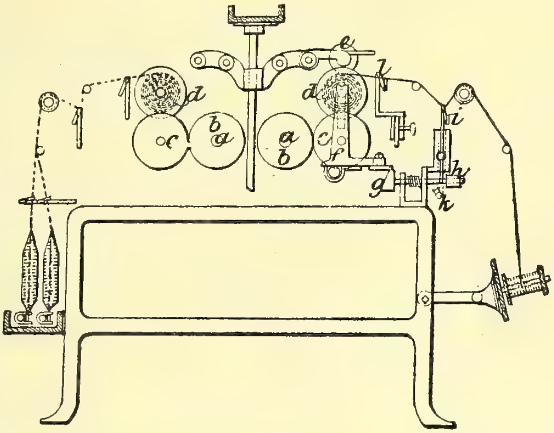


1187.



Winding.—Formerly the threads or yarns contained in the strands were wound by hand into a ball from a creel containing the requisite quantity of yarns, but this system, owing to the irregular draft of the threads by the hand, and the twist imparted by balling, only yielded an indifferent quality of twine. Several machines have been invented to obviate the defects of hand-winding, with more or less success. Fig. 1187 is an illustration of one of the most recent and perfect of doubling-winding-machines, as machines for winding several threads together upon one bobbin are called. It is described by the inventor, T. Unsworth, Manchester, as a direct-acting, draw-bolt, positive stop-motion, doubling-winding-frame. With slight modifications, chiefly in dimension, it can be adapted for working any description of fibre—silk, cotton, wool, flax, jute, or hemp, and in any degree of fineness. It can be constructed to wind any number of threads upon one bobbin: it is usually made for 15–20. A shaft *a* (Fig. 1188) bearing upon the ends of the frame extends throughout its length, and is fitted with friction-drums *b*, and, projecting beyond the frame, also carries the driving-pulleys. Each drum has a similar one *c* adjusted to be driven by the friction of the one first mentioned. The second drum is in contact with and drives the bobbins *d*. Over the bobbin, is placed a porcelain pressure-bowl *e*, which works in contact with the yarn upon the bobbin. Beneath the second drum, and hollowed to fit its periphery, is a brake, into which, by the action of the stop-needle, the drum is made to fall. This drum *c* is fitted upon a lever *f*, the opposite end of which projects towards the front of the machine, extending to and resting upon the draw-bolt *g*—a bar covered with a spiral spring to hold it in position, and which sustains the bolt in contact with the driver drum. The reverse extremity of the draw-bolt has a cross-piece *h* attached, thus forming a representation of the letter ⊥ laid horizontally with the cross-piece outwards. In the oblong frames affixed near the front of the machine, each of which is horizontally divided by a bar through the middle, are inserted the direct-action stop-needles *i*, which constitute the chief feature of the machine. The needles are composed of two parts, looped together (Fig. 1187). On the upper part, is a curl through which the threads pass; the lower part, pendant by the loop from the upper, drops its extremity on the inner side of the cross-piece of the ⊤-shaped draw-bolt *h*, and the outer side of a rocking-bar *k* extending the length of the machine, which is actuated by eccentrics.

1188.



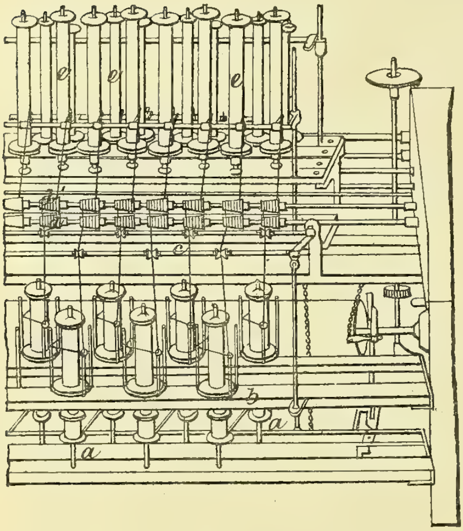
The cops or bobbins having been placed in the creel, the threads from each are conducted upwards through the first eyelets, thence over a glass rod, through the curls of the stop-needles, and around the revolving porcelain bowl or curl *l* of the yarn-guide, whence they pass upon the bobbin. The action of the machine is as follows:—The needle, by means of the thread, is suspended at such a height as to be clear of the rocking-bar; but when the thread sustaining it breaks, it instantly falls, its lower extremity dropping in front of the rocking-bar, which strikes it against the draw-bolt, pushing the latter forward so as to release the end of the lever supporting the second friction-drum, which instantly drops into the half-round break, and at once stops the revolution of the bobbin without friction.

The chief objects sought in doubling-winding are uniformity in the lengths of the threads laid together, equality of tension, and freedom from "single" caused by dropped threads. All these faults are discovered in subsequent processes, showing themselves in "cork-screws" and other defects, which greatly deteriorate the quality. The lengths may vary through irregularity in winding, caused by a varying amount of friction upon the different bobbins, or an uneven deposit of the yarn upon the barrel of the bobbin. But by this machine, both these faults are prevented: the first by the suspension of the stop-needle upon the thread, which takes up any momentary slack; and the second by the threads being passed in a tape-like band over the revolving bowl upon the traverse-rod, which deposits it evenly upon the bobbin, which the pressure-bowl further helps to render firm and level. "Single" is prevented as previously described. The pressure-bowls are made of 3–20 lb. weight, according to the nature of the fibre upon which the machine is to be employed.

Twisting.—The bobbins containing the threads necessary to form a strand are conveyed to the twisting-machine, an improved form of which is shown in Figs. 1189, 1190. The twisting-spindle *a*, which receives the bobbin from the last-mentioned frame, occupies the ordinary position; but its flier, which has two or four legs as may be required, is inverted, and brought down upon the spindle to near the bolster-rail *b*, resting upon a metallic washer, which carries one of cloth or flannel, by means of which an easy drag of the bobbin is obtained. The inversion and change of position of the flier give increased steadiness to the spindle, especially when running at high velocities, and thus, at less expense in wear and tear, a greater production and superior quality of yarn are obtained. The attainment of high speeds in this machine is greatly facilitated by the bolster-rail not being a traverse-rail as well; all the weight of the yarn, bobbin and flier is concentrated upon the bearing, while the spindle is reduced to the size of the bobbin. The unwinding traverse is obtained by passing the yarn round one leg of the flier.

After leaving the bobbin, the yarn passes over a carrier-rail *c*, and upon the twist-rollers intermediate between the delivery- and the taking-up-rollers. The twist-rollers *d d′* are conical grooved pulleys placed upon parallel horizontal shafts, one function of the first row being to draw the yarn from the bobbins, whilst the revolving spindle puts in the twist. The yarn passes upon one of the smallest grooves of the cone *d*, and over a larger one in the cone *d'*, which stretches the strand and lays the yarn well together before it passes upon the taking-up-bobbin *e*. The last-mentioned bobbin can be made of any required dimension, as, its only function being to take up the yarn when twisted, weight is no objection. In the sectional view, the twist-rollers are shown with an alternative arrangement.

1189.



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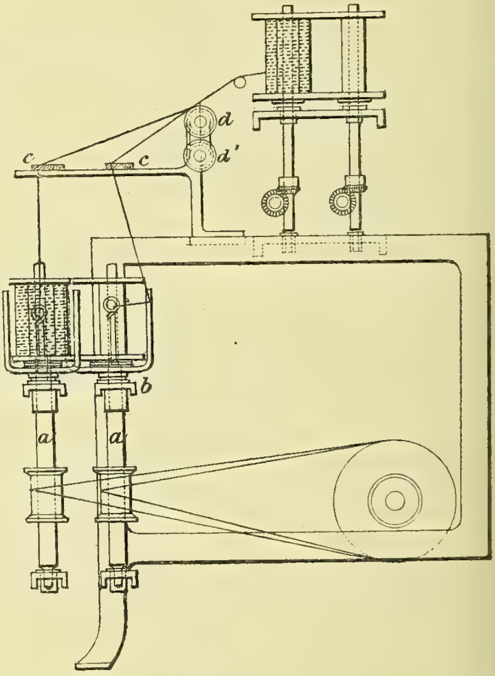


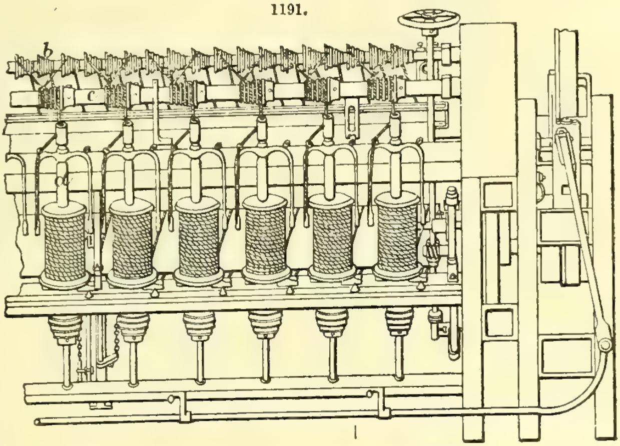
This machine, one of whose novelties lies in its being an "upward twister," has a great productive power. One of 200 spindles will turn off 2400 lb. a week of 3-fold 8's cotton, 9 turns an in., which is $\frac{1}{3}$ more than can be obtained from ordinary machines. One girl can superintend the machine, creeling and doffing without assistance. Owing to the employment of large winding and taking-up-bobbins, a greater length of yarn can be produced without a knot; and through the stretching on the cones, the twisted strand is made round, firm, and full. The cost of warp-winding is also saved, as the machine winds the yarn upon large warping-bobbins during the operation of twisting; less space and power are also needed.

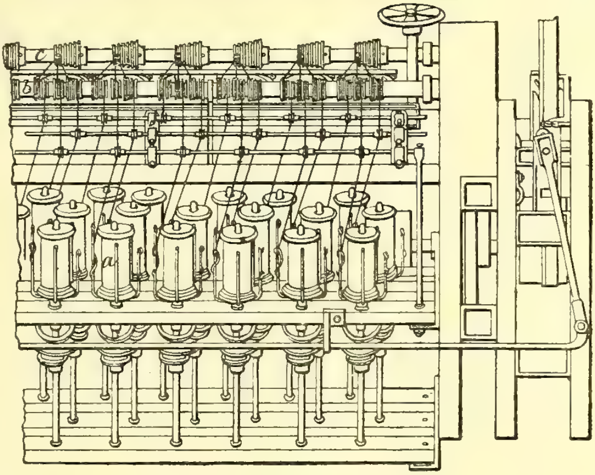
For heavy fibres, as flax, hemp, and jute, strong machines are constructed, which deal with them as efficiently as the light ones do with wool, silk, or cotton. The winding or twisting-bobbin for heavy fibres may be made up to 8-in. lift and 5-in. diam., capable of holding $3\frac{1}{2}$ lb. of yarn, and, in these dimensions, can be worked up to 2000 rev. a minute. For "once-twisted" or "hung-on" twines, as the Scotch call them, the machine possesses great advantages.

In the manufacture of cable-laid twines or cords, the following machine is employed in several large establishments (Figs. 1191, 1192, 1193). The bobbins from the doubling-winding machine, Fig. 1187, are brought to this machine, and placed upon the back spindles containing the inverted fliers *a*, Fig. 1193, the strands being conducted over the guide-rails, to the back twist-rollers, which draw the yarn from the bobbins as in Fig. 1189, whilst the revolving spindles similarly put in the twist. Each strand is placed upon the smallest groove of the cone-shaped rollers *b*, then around the others, to the top one of largest diameter, by which means it is stretched the difference between the largest and smallest diameter, which imparts firmness and great solidity to the strand. This constitutes the first twist or lay; the second twist or cabling is imparted by passing three strands from three of the cone-rollers just mentioned over the cone-rollers *c* on the front or second shaft, by which they are laid together, and passing round grooves as before, are again stretched, delivered to the topping-motion, twisted by the powerful spindle and flier *d*, and wound upon large bobbins, often of 8-in. traverse by $6\frac{1}{2}$-in. head. This machine contains two driving-cylinders, one each for the front and back, so that the amount of either first or second twist can be regulated with nicety and ease.

One of these machines 11½ by 5½ ft., containing 30 back and 10 front or finishing spindles, is capable of yielding a production of 1500 lb. of 1-lea laid twine a week, one girl superintending. It makes all kinds of twine, from fine to coarse, and hard or soft, according to requirement; and includes such diverse articles as spindle-bandings, piping-cord, heavy fishing-net twines, fishing-lines, loom-cords, hair-cords, three-cord cabled twine, trimmings, and fancy cords of all descriptions.

1191.





1192.

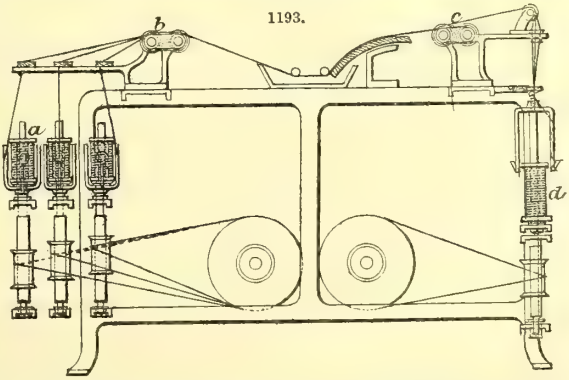
In bandings for spindle-driving purposes, the stretching operation upon the cone and grooved rollers is exceedingly valuable, as when the bands are put to use, they never become slack through stretching, and thus enable far better yarn to be produced than when banding made on the old process is employed.

At the Centennial Exhibition, held in Philadelphia, the series of machines of which these form a portion secured to the patentee, Thos. Unsworth, medal, diploma, and certificates for originality, perfection and utility, combined with fitness for purpose intended, quality of products, and economy of working.

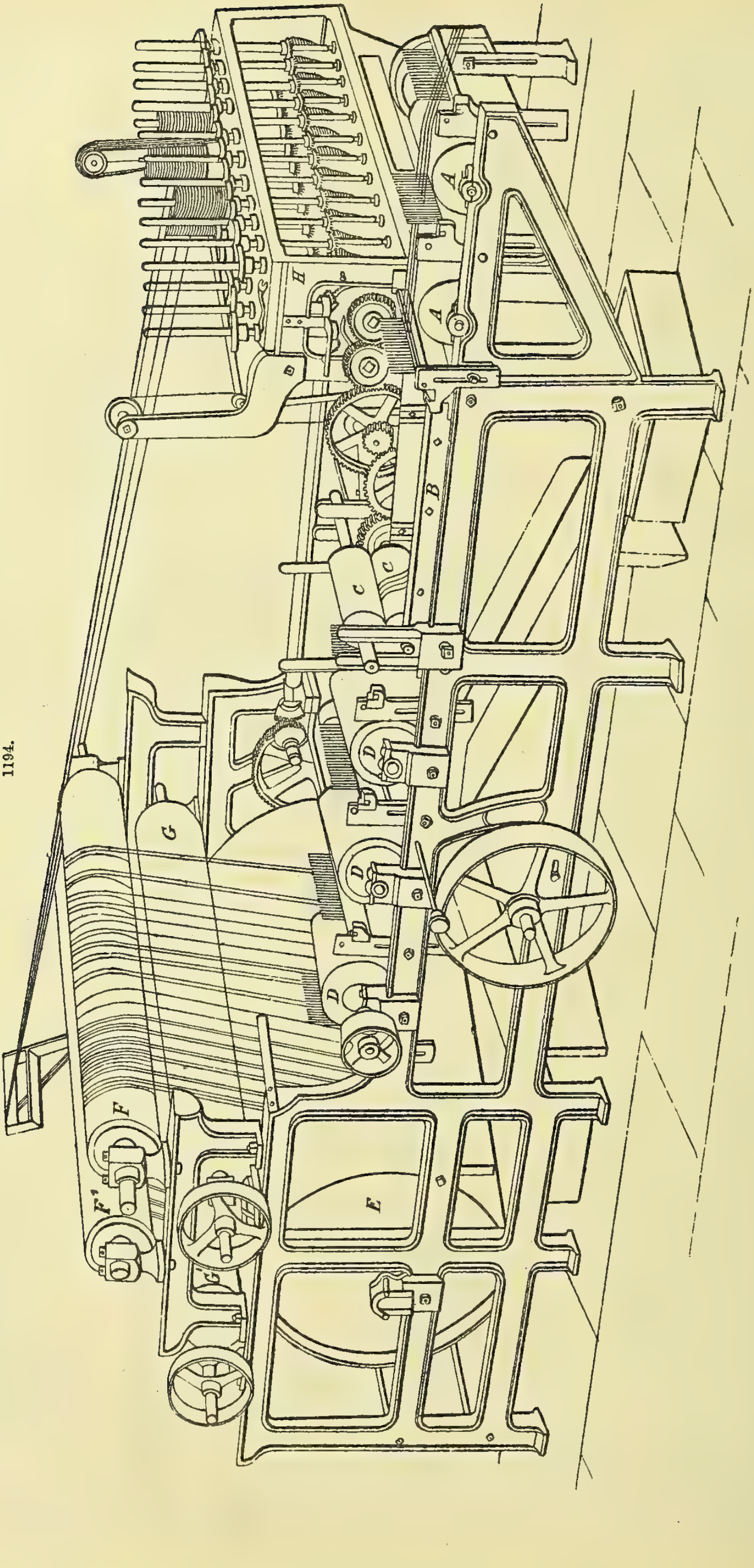
There are several other varieties of winding, twisting, and cabling-machines of considerable merit, but which call for no special notice here.

Singeing.—Twines made from harsh or intractable materials require to be singed before sizing and polishing, which are the finishing processes of this class of articles. Singeing-machines are usually constructed in the form of a winding-machine with about twelve spindles at back and front, the latter drawing the yarn or twine through a jet of flame obtained from a combination of gas and atmospheric air. Sometimes other means are employed to obtain a flame, such as oil-lamps.

1193.



Sizing, Polishing, and Drying.—The operations of sizing, polishing, and drying are generally included in one machine, though, by the older processes, they constituted three distinct operations. Fig. 1194 represents a sizing-, polishing-, and drying-machine, as constructed by Thos. Barraclough,



1194.

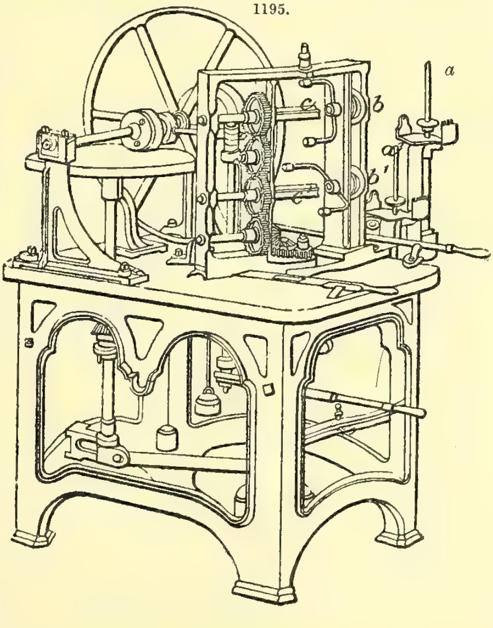
Manchester, who is also the maker of the remainder of the machinery subsequently illustrated in this article, except when otherwise stated. This machine is generally constructed of such a capacity as to take 24 twines at once. The filled bobbins from the twisting-frame, Fig. 1189, are placed in a creel in front of the sizing-machine, and the twines are conducted in parallel order over the carding-rollers A, which are covered with card clothing of suitable strength, and which, revolving at a high speed, brush off the woody portions of the plant, shive, boon, and lumps that may have remained through the preparing stages, leaving the twines smooth and clean. The twines are kept apart by the three sets of vertical guide-wires, from the third of which they pass into the sizing-trough B, a copper or iron tank containing steam-heated size, composed of flour or farina, glue, animal gelatine, or other materials, and brought to the required consistency by means of water. Hot size is indispensable to a satisfactory result; cold size merely coats the surface, and would soon break and rub off in wear. In the spinning and twisting processes, it is impossible to combine the fibres into a *solid* thread; in the interstices, is a considerable quantity of atmospheric air, which, on the twines passing through the boiling size, is expanded by the heat, and escapes, the space it occupied being instantly filled by the hot size, thus ensuring a comparatively solid cord. Emerging from the size, the twines pass between two pressing-rollers C, which squeeze out the superfluous size, and return it to the tank. Guide-wires capable of being depressed, so as to make the twines cover a greater or less portion of the periphery of the rollers D, which are covered with coir, conduct them over these in succession, by which the loose fibre is rubbed in, and a smooth surface is ensured. After leaving these rollers, the twines pass upon the large cylinder E (which is heated by steam), and helically around it several times, being directed by two guide-rollers F F′, so as to pass off the cylinder at the opposite side from that on which they enter. The drying is also facilitated by the circulation of air in the helical interstices formed by the presence of the twines. The polishing process is continued by the action of two rubbing-rollers G G′, extending across the length of the cylinder, and similarly covered with coir. One of these revolves against the outside of the set of twines during the passage round the drying-cylinder, and the second polishes the under surface revolving in the space formed by one of the angle rollers, thus completing the polishing operation. The twines, on leaving the rollers, are conducted over two carriers to the winding-frame H at the front, which contains an equivalent number of spindles, and winds the twines upon the bobbins with which they are filled. In the figure, only four threads are shown, for the sake of clearness.

The composition of the size used is of considerable importance, when the best result is desired. An authoritative writer has recently given the following as a good practical recipe:—36 lb. wheat-flour is mixed with cold water until a paste is formed; 22 gal. of water is put to boil, and 2–3 lb. of cow-horn glue, Irish moss, or animal gelatine, 5 lb. of alum, and 6 lb. of tallow are added; when boiling, the paste is added, and the mixture is boiled until it thickens, when it is ready for use in the machines. This is a good compound for medium and heavy twines; for fine twines, the alum, and half of the tallow, is usually omitted.

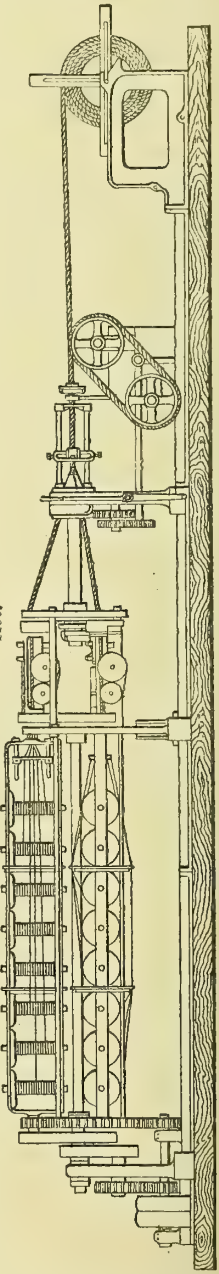
The sizing-machines are made in two sizes; in the smaller, the drying-cylinder is 72 in. across the face, and 30 in. diam., and will size 1000–1800 lb. of twine in a week of 60 hours. This is the most suitable for light descriptions of twines, the drying of which is not difficult. The larger one has a drying-cylinder 96 in. long, and 36 in. diam., and will size, polish, and dry 1800–3000 lb. in 60 hours. This is employed for heavier twines; but for the heaviest, it is necessary to have two cylinders, in order to dry them thoroughly.

Sizing is sometimes regarded as a needless and expensive process, but the weight imparted to the twine is ample compensation for the expense (yarn being generally sold by weight), while the improvement in the quality is undoubted.

1195.



Balling.—Balling is the last and finishing process in the manufacture of twine. Two bobbins of polished twine are placed upon the vertical spindles *a a′*, in Fig. 1195. The twines are taken from these, passed through the necks of the fliers *b b′*, and down one leg of each, whence it is wound upon the horizontal spindles *c c′*, which, by other appliances, have imparted to them the peculiar automatic movements required to form the twine into balls. As the balls attain the required weight, they are doffed and finished by the attendant girl lapping the twine several times very firmly round the middle. In balling light twines, the double machine is usually employed; for heavy descriptions, the single one, making only one ball at a time. They are fitted to be worked by manual or steam power, as may be most convenient.


1196.

Ropes.—The section now calling for attention is the manufacture of fibrous ropes; these, as explained previously, are technically known as hawser-, shroud-, and cable-laid, besides flat ropes formed by placing several ropes parallel to each other, and uniting them by oblique stitches, thereby producing a flat band.

In manufacturing these articles, the raw material is treated as previously described in the preparatory stages, spun into yarn, a number of yarns twisted into strands, these into ropes, and the latter into cables. In these processes, it is invariably the method to twist the article in the direction opposite that of the preceding stage. Thus, supposing the yarn is spun with a right-hand twist, the strands into which this enters will be twisted to the left, and the rope into which these are combined must be twisted to the right, or in the same direction as the yarn, and so on with succeeding combinations. This is requisite to prevent or overcome the tendency that would otherwise exist to run into loops or kinks whenever the ropes were brought into use.

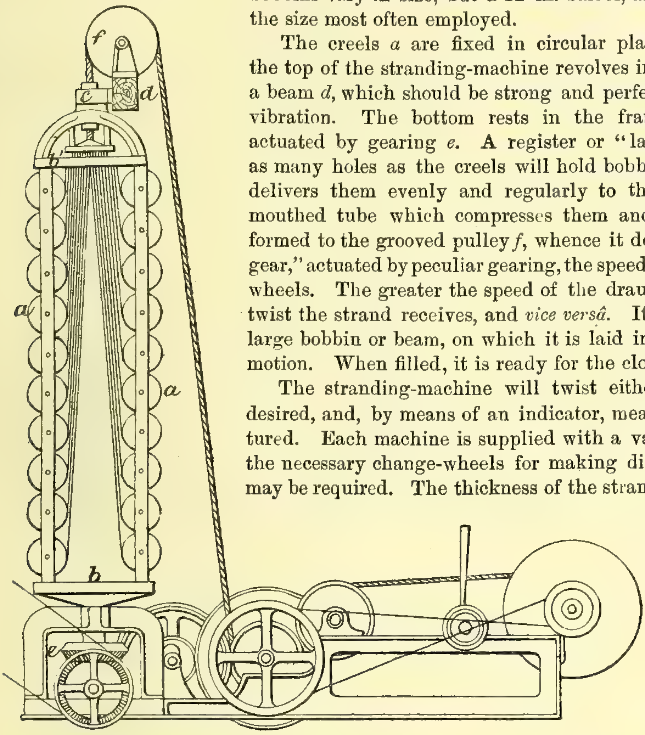
Necessarily the machinery for performing this heavy work differs considerably from that previously described, inasmuch as a machine seldom makes more than one article at a time. Again, to avoid excessive complexity of the machine, and the consequent liability to derangement, it is usually found preferable to employ machines for each operation, instead of combining all in one. Especially is this the case in the heavier classes of ropes and cables. In the lighter articles, compound machines are frequently used. These are of two kinds, the vertical and horizontal, the former being employed in the manufacture of long ropes, and the latter generally of shorter lengths.

Laying.—A small horizontal compound rope-laying machine is shown in Fig. 1196. The largest rope of three strands that could be made on this machine would be one of 24 yarns—8 to each strand. It will serve to show the principle on which larger ones are constructed. By means of change-wheels, 3-strand ropes of smaller dimensions can be made upon it, containing 7, 6, 5, 4, 3, and 2 yarns to each strand, the ropes of course being a multiple of those figures by three. The machine has three fliers, each capable of containing 8 bobbins filled with yarn, which are placed in a creel inside the flier, and so arranged as to deliver their contents easily to the draught of the machine. The yarns are conducted through the trunnion of each flier, along the side, through the corresponding trunnion, and upon the three topping-motions. The revolutions of the fliers twist the yarns into strands, which are drawn forward by the topping-motions. The latter revolve with the fliers, and are furnished with grooved draw-rolls actuated by gearing. The strands pass upon and around these grooved draw-rolls, which, being coned, stretch and solidify them before they pass from the stranding part of the machine, and are combined into a rope in the front portion, as shown in the illustration, by their passage through machinery similar to that which formed the strand. The finished rope is wound upon a barrel driven by a differential gearing, in even layers, and when completed, is easily removed by doffing, the barrel being collapsible; the machine is thus ready for work again in 2–3 minutes.

As will be seen, the machine is compact, simple, efficient, and of great productive capacity, being capable of making 1000–1600 fathoms of rope a day, according to the size, twist and other circumstances that usually affect production. It is made in various sizes, to suit different requirements; when larger ropes are intended to be made, say up to 60 threads, the form is considerably modified. In both sorts, the sizes of the ropes can be altered by the use of change-wheels.

When the manufacture is more varied, it is usual to employ single machines, performing only one operation. The first of these is the stranding-machine, which may be either vertical or horizontal. Fig. 1197 represents a vertical machine, technically called a "stranding-drum." It consists of 2 vertical bobbin-frames; others contain more—4, 5, and up to 10. These creels may be made for any required number of bobbins, and usually contain 4–12. The bobbins vary in size, but a 12-in. barrel, and 12-in. diam. of head, is the size most often employed.

1197.



The creels *a* are fixed in circular plates *b b′* at top and bottom; the top of the stranding-machine revolves in an iron bracket *c*, fixed to a beam *d*, which should be strong and perfectly firm, so as to prevent vibration. The bottom rests in the framework, the whole being actuated by gearing *e*. A register or "lay" -plate, perforated with as many holes as the creels will hold bobbins, receives the yarns, and delivers them evenly and regularly to the "stranding-die," a bell-mouthed tube which compresses them and delivers the strand thus formed to the grooved pulley *f*, whence it descends to the "drawing-off gear," actuated by peculiar gearing, the speed being regulated by change-wheels. The greater the speed of the draught, the less the amount of twist the strand receives, and *vice versâ*. It is next conducted upon a large bobbin or beam, on which it is laid in even layers by a traverse-motion. When filled, it is ready for the closing-machine.

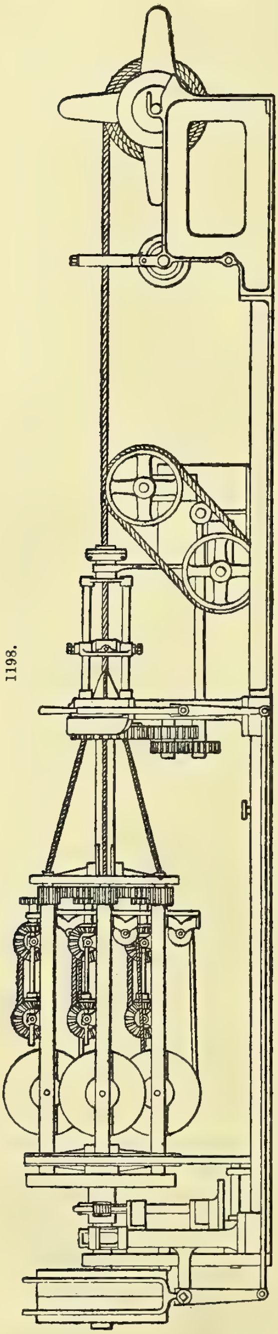
The stranding-machine will twist either to the right or left, as desired, and, by means of an indicator, measures the length manufactured. Each machine is supplied with a variety of strand-tubes, and the necessary change-wheels for making different sizes of strands, as may be required. The thickness of the strand is varied by increasing or diminishing the number of yarns contained therein, and also by changing the size or fineness. The machine should be strong, and carefully fixed, in order to produce good work, with an economical expenditure of power. The top of the machine generally extends into the floor above its base, in order to facilitate creeling operations; a platform is also used for the same purpose.

Another form of the stranding-machine—the horizontal,—which possesses several advantages in the facility with which it can be worked, has of late years been coming into general use. It possesses a fixed creel, in which the bobbins can be renewed without stopping the frame, and may be varied in number to any extent. Its production is much greater, it being capable of running at a much higher speed; and the strand-tube, being fixed in an iron box, can be heated either by gas or steam, which polishes the strand to a high degree, and facilitates the process of tubing "hard."

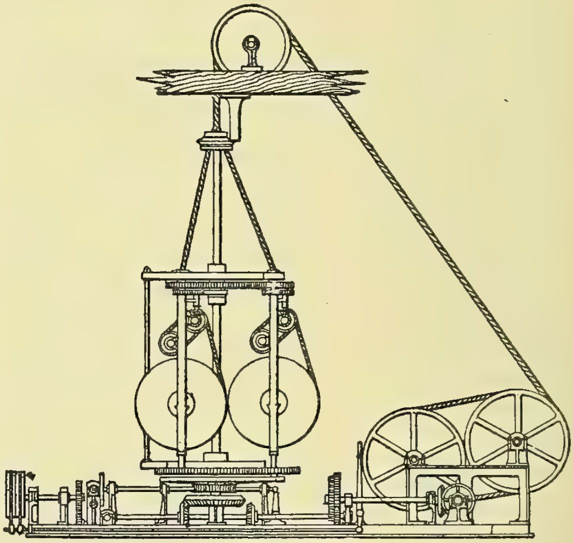
Closing.—The hemp-rope closing-machine, which receives the strands from the former, and "lays" them into a rope, is also made in two forms, the vertical and horizontal. In the latter, Fig. 1198, the construction does not differ materially from that of the horizontal compound rope-laying machine, Fig. 1196, except in its greater simplicity, owing to having fewer operations to perform. The vertical closing-machine, Fig. 1199, has a strong cast-iron frame, and three or four cast-iron frames or creels for the reception of the large cast-iron strand-bobbins, containing the strand manufactured on the stranding-machine. These are caused to revolve by means of suitable gearing, both on their own axis and around the central vertical shaft, the top of which is secured to a strong beam in the building. This action causes the strands to come together, and close at the top of the machine, after which, the rope passes over a sheave or pulley, then down through the drawing-off gear, and upon the coiling-reel, which portion, omitted from the illustration, is made adjustable both in width and diameter, to suit the various sizes of coils required to be made.

These machines are also constructed in various sizes to suit requirements, and have several attachments, not shown in the illustration, such as a regulating drag-gear for delivering the strands at a uniform rate, which is of the greatest importance in securing a well-made rope. The large machines possess in addition a "tempering-motion," the purpose of which is to impart, as may be required, more or less twist to the strands when being laid into ropes. Ropes, according to the uses for which they are intended, require a greater or less amount of twist, and this can be exactly regulated by the "hardening" or "softening" process at the time of closing. It is usual, therefore, for every closing-machine to possess a tempering-motion, without which, it would be incomplete. The machine is made so that its parts will revolve in either direction, so as to make a rope with either a right- or left-hand twist. In the manufacture of shroud-laid ropes, in addition to the four creels or frames for the strand-bobbins, another is required for the core-piece, which is drawn off at the speed at which the rope is laid. Before coming together, the strands have to pass over a "top," the object of which is to deliver them at exactly the same angle and distance, one from the other. These tops are either of wood or iron, but the former are mostly preferred, because, wood being a better non-conductor, the heat generated by the frictional passage of the strand smoothes and polishes it far better than in an iron top, where the heat is dispersed by radiation.

1198.



1199.



Each machine is capable of making a considerable variety of sizes of ropes, varying in the degree of lay or twist, which is accomplished by altering the speed of the drawing-off motion, by means of change-wheels. Similar means are also provided for varying the drag- and tempering-motions, according to requirement.

The various machines, whether vertical or horizontal, required in the processes of stranding and closing are always worked in sets, which generally include two stranding- and one closing-machine to a set, though sometimes three of the former and two of the latter are wrought together, forming what is called a double set.

The standard sizes of the machines—at least of those under description—are indicated by letters, and are as follows:—

Set E.	horizontal,	makes ropes	up to	1¼	in.	circum.
„ F.	„	„	„	2½	„	„
„ G.	„	„	„	4	„	„
„ H.	vertical	„	„	4	„	„
„ I.	„	„	„	6	„	„
„ J.	„	„	„	10	„	„

These sizes are based on a length of 120 fathoms in each coil. Where shorter coils will suffice, each set will produce thicker ropes. Their capacity of production is governed by that of the closing-machine, which can always be ascertained by multiplying the length in in. of the turns or twist in the sample, by the number of revolutions the closing-machine is making a minute, and the product will be the number of in. that will be made in the same time. A percentage, which experience will soon dictate, must be deducted from this for stoppages, the remainder being a practical result.

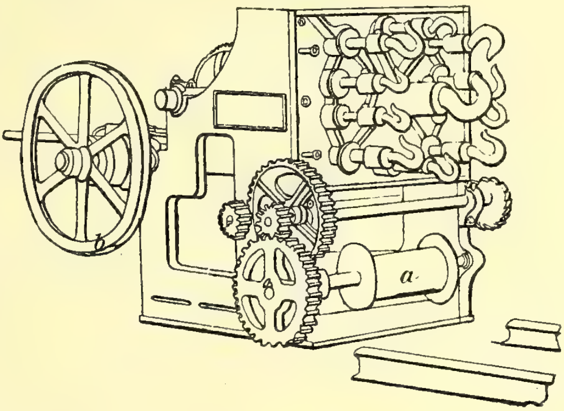
The closing-machines of the different sets make the following revolutions a minute:—E, 130; F, 100; G, 70; H, 60; I, 50; and J, 30.

One man usually superintends a set of machines, taking charge of the closing-machine himself and having assistant boys or girls at the stranding-machines.

The preceding account shows the extent to which the rope-making industry has been revolutionized by the invention of machinery, in comparatively recent years. But even this does not exhibit the full extent of the changes that have been wrought. The old system of making ropes, as previously described, in long rope-walks by machines working in pairs still survives, and in fact, remains the most widely in use. The machines employed, in what may be termed the more ancient form of rope-making establishments, have also been greatly modified and improved, whilst their general outline and method of operation remain comparatively the same. Having already described the former, a brief account only will be necessary of the improvements recently introduced.

The "fore-board" has given place to the "foreturn-machine," Fig. 1200, and the "sledge" to the "traveller," Fig. 1201. In the best-furnished rope-walks, as distinguished from rope-factories, these machines are now generally found. They are used for both the stranding and laying processes.

1200.



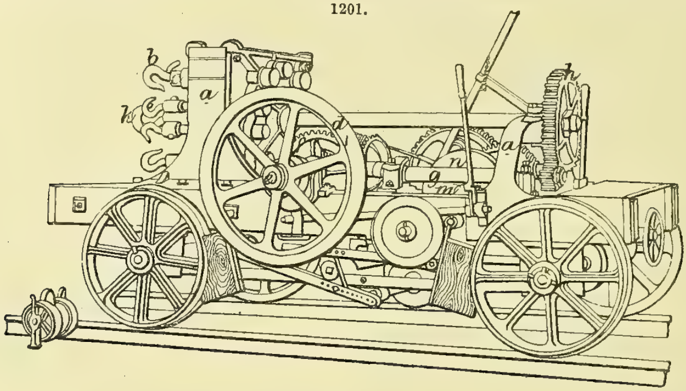
The yarns from which the strands are formed are contained on bobbins placed in the "bobbin-bank" or creel, generally a V-shaped frame with the apex directed towards the rear of the foreturn-machine, to which the yarn is delivered. These creels may, however, be of different forms, according to convenience or requirement, keeping in view the necessity of maintaining the bobbins in a compact arrangement, and enabling them to be easily accessible for the purposes of renewal when their contents are exhausted, and piecing or splicing when the yarn breaks, or faults occur. As these creels require to contain 100–400 bobbins, the importance of these considerations will be obvious.

After leaving the creel, the yarns are conducted through a register-grid—a frame containing a number of vertical round-iron rods, transversely crossed by others, thus forming square interstices, each thread having its separate square. This grid is for the purpose of conducting the yarns in parallel order to the register-plate—a cast-iron plate drilled with round holes arranged in concentric circles, through which the yarns are passed in such a manner as to dispose themselves in passing therefrom in a compact form round one central thread, which thus forms a core. The diameters of the register-plate circles are relatively such as to allow the threads in each circle to arrange themselves at the best ascertained angle, in order to compose a solid strand, and receive the general twist necessary to form it. Passing through the register-plate, all the yarns are next conducted to a strand-tube—a bell-mouthed, slightly tapering, iron tube, which usually passes through a steam-chest, by which means it is heated, to prevent ropes made of tarred yarns sticking fast, in which case they would have to be cut out, thus occasioning waste, defective work, expense, and inconvenience.

The yarns from the "bobbin-banks" are divided so as to form as many strands as are required for the rope to be manufactured. One register-grid suffices for all, whilst an assortment of register-plates is usually required: one for single strands of large diam., having only one series of circles; one for 3 strands with 3 series of circles; one for 6 and one for 12 strands. Each strand has a separate tube. Large strands are usually made singly, but those of moderate dimensions are made 3–12 at a time.

After passing the strand-tube, the yarns for each strand are immediately attached to the hooks of the traveller. The "traveller," Fig. 1201, consists of a powerful iron frame *a a*, in which are mounted a series of wrought-iron hooks *b*, attached to the ends of steel spindles *c*, driven by means of appropriate gearing, the speed at which they revolve being regulated by change-wheels. By means of clutches the direction of their revolution can easily be reversed. Motion is communicated to the traveller by means of an endless driving-rope, which extends from one end of the rope-walk to the other, and passes round the grooved pulley *d* on the shaft *e*; this through the bevel-gearing *f*, actuates the shaft *g*, which again, through the gearing *h* and shaft *i*, revolves the large central hook *k* in the traveller-breast. The shaft *e*, through suitable means, also actuates the shaft *m*, carrying the sheave or grooved wheel *n*, round which, passes a ground rope or chain, which is also attached to the "foreturn" machine, and extends the length of the rope-walk. The whole of this machinery is mounted on a stoutly-made carriage, composed of very strong materials, having powerful brakes, and running upon a rail or tram-car.

1201.



Assuming that it is a 3-strand hawser which is being made, the three sets of yarns, on leaving the strand-tubes, are attached to three hooks of the traveller. The endless rope passing round the grooved wheel *d* actuates the different parts, including the ground rope sheave *n*, the revolution of which causes the "traveller" to run down the walk, drawing the strand-yarns with it through the tubes, which, at the same time, are being twisted by the revolving hooks on the traveller to which they are attached. The strands, as they come from the hot tubes, are quite smooth, round, and polished.

It is now that the "foreturn" is required. This machine, Fig. 1200, is a strong massive frame, mounted with a series of revolving hooks, corresponding to those of the traveller, and actuated in a similar manner. It also possesses a winch *a*, for tightening the ground rope or chain. It receives its motion, like the traveller, from the endless rope or chain that passes over the grooved wheel *b*. This endless rope is the means by which motion is transmitted from a large grooved pulley on the main line-shaft of the works, and which is ordinarily placed under ground. A friction-box is connected with it, in order to ease the starting of the rope-laying machinery.

In order to form the three strands made on the traveller into a rope, their ends are cut near the "foreturn," and attached to three of its hooks, corresponding to those of the traveller. The latter are then made to revolve, in order to "temper," or put into the strands just the amount of twist required. The ends of the strands attached to the three hooks of the traveller are then transferred to one hook: its centre hook, if the rope to be laid is a heavy one. The "top," or longitudinally-grooved cone of wood, is then inserted between the three strands, with its smaller end towards the traveller, and the process of laying is commenced. The top is usually mounted on a small bogie or carriage, placed on the rails on the front of the traveller; and as the twist is put in by the central hook of the traveller in its revolution, the bogie starts away from it, and travels slowly towards the foreturn-machine at the head of the walk, being impelled by the closing of the strands. The rope is twisted in a direction opposite to that of the twist of the strands, but the quantity of the latter is preserved by the continued revolution of the hooks of the foreturn, to which their opposite ends are attached, and which revolve so as to give compensation for the twist being taken out by the traveller. A looped rope made of hair or coir is placed upon the newly-formed rope, and attached to the bogie; this acts as a polisher, smoothing and laying the fibres.

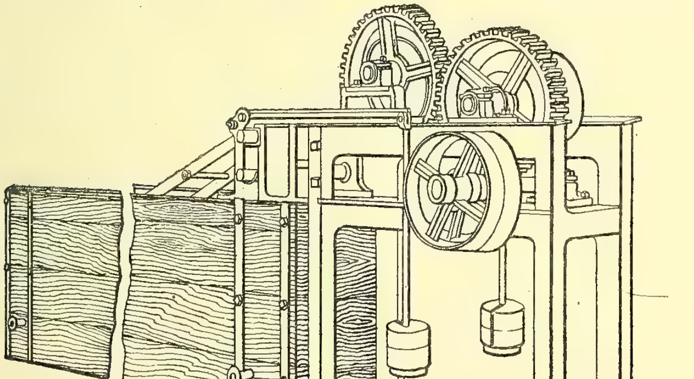
As the twist is being put into the rope, the length is greatly shortened, which draws the traveller up the walk. In order, however, to stretch the rope thoroughly, this draught is resisted as much as possible by the application of powerful brakes to every wheel. When the bogie carrying the top has reached the head of the walk, the rope is finished, and is coiled by power on an adjustable coiling-machine, which can be altered to make any size of coil. The traveller is brought up the walk to the foreturn by means of a brake, which prevents the revolution of the first motion shaft, and the rope, gripping the wheel, causes the traveller to run up the walk at the same rate as the driving-rope.

Both the machines here described are made in a great variety of sizes, and with different numbers of hooks, according to special requirement. Their capacity is very wide, as they will make ropes from the smallest sizes up to 24 in. in circumference. In order to be of the greatest use, they require a full complement of change-wheels and strand-tubes. Sometimes a foreturn will have two travellers, one light and one heavy. When one is in use, the other is run into a siding, or on to an extension of the line beyond the requirement of that in use.

The selection of the factory or walk system of manufacture will generally be decided by the special circumstances of the case, as each has its advantages and disadvantages. The factory or "house" machines, as they are called, are said to be capable of turning off more rope of a better quality, and at less cost for wages and driving-power, than the "walk" machines, though this is a disputed point. They need much less space for their operations, no "walk" and long shed being required. But the machines are numerous and expensive, where a full equipment is necessary, the first outlay and cost of maintenance being greater than when the foreturn and traveller are the chief machines employed. The latter are the simplest, and, where land and labour are cheap, may in some cases be the most advantageous.

The greatest proportion of ropes manufactured are made from tarred yarns. There are two methods of tarring in use: in one, the yarns are tarred singly; in the other, by the "haul." Yarns are tarred singly by arranging a number of large bobbins, usually about 16, on which the untarred yarns are wound, in a creel in front of a double-cased copper steam-vat, in which the tar is kept boiling by means of steam circulating in the cavity. In the pan, a copper or brass roller is adjusted, partly immersed in the tar. Over this roller, the yarns are conducted, and as they pass in contact with it, receive some of the boiling tar, which it brings up in its revolution. The yarns are next drawn along a copper trough, in which are placed hide ropes twisted tightly round them, whose function it is to equally distribute the tar, and, by friction, to lay the fibres, and polish the yarn. Leaving the trough, they are wound upon a large reel, and formed into a haul. In tarring in the haul, the yarns are wound upon a large reel, or warping-mill, in a helical form by a traversing motion, before being subjected to the tar. When the first layer is complete, the threads are passed round a pin or peg, and the motion of the reel is reversed until a second layer is completed. These operations are continued until a warp containing 200–400 threads is made, which is then wound off, and coiled on a revolving plate or iron dish upon a bogie, which is made to revolve for the purpose of imparting to the warp a few turns of twist, to prevent the entanglement of the threads in passing through the subsequent processes and during mellowing. The warp is then taken to the tarring-machine, Fig. 1202, consisting of a large trough or cistern, in which the tar is kept at boiling heat by means of coils of copper steam-piping. The yarn or warp is conducted through the boiling tar, and the pressing-apparatus, being drawn through by means of the gearing actuating the sheaves, around which it is twice passed to prevent slipping, and is then coiled for the store. The difference in these processes is not very material: in the first case, the yarns are tarred before they are made into a warp; in the second, after that operation. In tarring singly, the yarns are warped as they emerge from the tar-pan.

1202.



When the tarring process has been completed, the "hauls" or tarred warps are conveyed into the store, in order to be mellowed, which is simply allowing the tar to penetrate the fibres. The time for this varies according to the quality of the work for which they are intended. Two months is stated to be the shortest time in which this can be accomplished; it is done much better when 6–8 months are devoted to it. In the Royal dockyards, it is customary to allow 12–15 months for the process. The tar used should be clear and of a light colour, in order to impart the best appearance. Contact with iron, when it is fluid, darkens and discolours it, and this should therefore be carefully avoided.

When the tarred yarns are required for use, they are brought from the mellowing-store; the warps are wound upon the reel; the threads are separated, and wound upon bobbins from the reel, thus reversing the previous operations; and the bobbins are conveyed to the stranding-machines to pass through the processes previously described.

Exports.—Our exports of cordage, cables, and ropes of hemp and similar material in 1880 were to:—Australia, 16,665 cwt., 54,155*l.*; British N. America, 16,264 cwt., 34,766*l.*; British W. Indies and British Guiana, 8886 cwt., 18,662*l.*; Brazil, 8409 cwt., 23,237*l.*; British S. Africa, 7074 cwt., 17,767*l.*; Argentine Republic, 6378 cwt., 11,487*l.*; Germany, 5130 cwt., 12,823*l.*; France, 4027 cwt., 8942*l.*; Sweden and Norway, 3615 cwt., 10,272*l.*; Bombay and Sind, 3589 cwt., 8963*l.*; Chili, 3356 cwt., 7564*l.*; Peru, 2767 cwt., 5355*l.*; Italy, 2531 cwt., 5696*l.*; Japan, 2399 cwt., 4944*l.*; United States, 2018 cwt., 4169*l.*; Bengal and Burma, 1927 cwt., 7642*l.*; British W. Africa, 1270 cwt., 4214*l.*; Channel Islands, 1048 cwt., 6000*l.*; other countries, 20,964 cwt., 48,949*l.*; total, 118,307 cwt., 295,607*l.* R. M.

(See Fibrous Substances.)

SALT (Fr., *Sel*; Ger., *Salz, Chlornatrium*).—Formula, $NaCl$; hardness, 2·5; sp. gr., 2·1–2·57.

If we consider the natural products of the earth in their relative economic importance, salt, one of the most abundant and universally diffused, commends itself pre-eminently to our notice. Yet comparatively little has been written concerning it, and the industry, one of the most important we possess, may be said, with the exception of a few trifling innovations, to be practically in the same position as it was 50 or 100 years ago.

Common salt (sodium chloride) may be directly produced by the combination of chlorine with sodium. It has been stated that sodium takes fire when immersed in chlorine gas; but Wanklyn has shown that, unless some moisture be present, such is not the case, and it is certain that metallic sodium remains bright for some time, even when immersed in liquefied chlorine anhydride. The composition of salt is:—

	Equivalents.	Percentages.
Chlorine	35·5	60·7
Sodium	23·0	39·3

A blue sodium subchloride is (probably erroneously) stated to be produced by passing hydrogen over sodium chloride at high temperatures. Salt is isometric; it crystallizes in anhydrous cubes, and other congeneric forms; its cleavage is perfect; taste, cooling and agreeably saline; when pure, it is white, and is often found in nature in pellucid and perfectly colourless crystals as rock-salt, but more frequently rock-salt is grey, rose, brick-red, yellow, violet, blue, or green, being stained by iron, bitumen, or other impurities. When crystals of salt form by evaporation on the surface of still brine, as frequently occurs in the manufacture, the cubes have a tendency to agglomerate themselves by their angular edges, so as to build hollow four-sided cups, called "hopper-crystals" (Fr., *tremis*). Fishery-, bay-, and dessert- salts illustrate this peculiar form of crystallization. Although salt crystals are anhydrous, they are liable to contain water mechanically intercalated between their crystalline plates, causing them to decrepitate when somewhat suddenly and strongly heated. This decrepitation rarely occurs with rock-salt, and only in a small degree with the heavier larger crystals of salt produced during the slow spontaneous evaporation of sea or other salt water. Salt fuses at 776° (1428° F.), and volatilizes, but not in covered vessels at a temperature approaching its point of fusion, sustaining thereby considerable loss of weight. When a saturated solution is cooled to − 10° (14° F.) or a few degrees lower, it crystallizes in hexagonal tables of hydrated sodium chloride ($NaCl+2H_2O$); and a further reduction of the temperature to about − 22° (− 5·80° F.) causes the separation of bundles of fibrous or needle-shaped crystals, having the composition of a cryohydrate, and containing ten equivalents of water ($NaCl+10\,H_2O$); both these forms deliquesce with the mere heat of the hand, and may be seen to resolve themselves rapidly with a species of decrepitation into sodium chloride solution and numerous small cubes of common salt.

Sodium chloride is decomposed slowly at a red heat in presence of aqueous vapour into caustic soda and hydrochloric acid, according to the formula $2NaCl+H_2O = 2HCl+Na_2O$. This fact has been utilized in an attempt to manufacture soda from common salt, by mixing salt with siliceous sand, placing the mixture in a retort, heating to redness, and passing steam; but the experiment gave no hopes of commercial success.

Salt is nearly as soluble in water at ordinary temperatures as at the boiling-point; and when a saturated solution is heated in a vessel admitting of evaporation, it crystallizes out, forming hopper-crystals at the surface if the liquid be maintained tranquil, or sinking to the bottom as a fine crystalline powder (butter-salt) if the liquor be kept in a state of agitation. Salt is one of the most highly diathermanous bodies, and at the same time one of the most perfect in its absence of thermochroic properties, permitting the passage alike of dark and of visible heat rays, and of heat rays of all degrees of refrangibility. Specimens of colourless pellucid rock-salt are therefore highly prized in researches on radiant heat. Transparent rock-salt transmits no less than 92·3 per cent. of radiant heat from every source, whether the radiating surface be highly incandescent, or the rays be invisible; while the best specimens of flint-glass transmit only 28 per cent. of the heat radiated by red-hot platinum, and still less of dark heat rays; and ice cuts off all radiant heat from either of these sources. Melloni regards clear rock-salt as being completely diathermanous, attributing the 7·7 per cent. by which the intensity of the incident rays is diminished to an effect of reflection at the surfaces of ingress and egress, not to interior absorption.

The annexed table by Poggiale shows the lbs. of pure salt dissolved by 100 lb. of water at various temperatures:—

−15° (5° F.)	dissolve	32·73 lb.	40° (104° F.)	dissolve	36·64 lb.
−10° (14° F.)	„	33·49 „	50° (122° F.)	„	36·98 „
− 5° (23° F.)	„	34·22 „	60° (140° F.)	„	37·25 „
0° (32° F.)	„	35·52 „	70° (158° F.)	„	37·88 „
5° (41° F.)	„	35·63 „	80° (176° F.)	„	38·22 „
9° (48°·2 F.)	„	35·74 „	90° (194° F.)	„	38·87 „
14° (57°·2 F.)	„	35·87 „	100° (212° F.)	„	39·61 „
25° (77° F.)	„	36·13 „	109°·7 (229° F.)	„	40·35 „

According to G. Karsten, a saturated solution of salt at sp. gr. 1·25 contains 26·535 per cent. of NaCl, and saturated at a boiling temperature, it contains 28·225 per cent.

The boiling-points of salt solutions of various strengths are given by Storer thus:—

Aqueous Solution containing per cent. of NaCl.	Boils at ° C. according to		
	Bischof.	G. Karsten.	Legrand.
5	101·50	101·10	100·80
10	103·03	102·38	101·75
15	104·63	103·83	103·00
20	106·26	105·46	104·60
25	107·93	107·27	106·60
29·4	107·9 to 108·99		

According to Gerlach, the sp. grs. of salt solutions at different degrees of concentration are:—

Aqueous Solution, sp. gr. taken at 59° F.	Contains per cent. of NaCl.	Aqueous Solution, sp. gr. taken at 59° F.	Contains per cent. of NaCl.
1·00725	1	1·11146	15
1·01450	2	1·11938	16
1·02174	3	1·12730	17
1·02899	4	1·13523	18
1·03624	5	1·14315	19
1·04366	6	1·15107	20
1·05108	7	1·15931	21
1·05851	8	1·16755	22
1·06593	9	1·17580	23
1·07335	10	1·18404	24
1·08097	11	1·19228	25
1·08859	12	1·20098	26
1·09622	13	1·20433	26·395
1·10384	14		

Salt is found as rock-salt in stratified beds, usually forming large, lenticular or rounded-oblong masses, imbedded in red clays or variegated marls, these being usually interstratified with gypsum or anhydrite. It is likewise one of the chief constituents of sea water, salt lakes, and brine springs, and occurs in small quantities in *all* rivers and springs. It is found in all surface soils, sometimes as an abundant efflorescence. Some desert regions of Asia, N. Africa, N. and S. America, and Australia, appear to owe their sterility to this cause. But probably at no period of the earth's existence did the formation of salt deposits proceed with the same activity as during the Triassic, and it is in the New Red sandstone, Bunter sandstone, or Keuper, and in the red or variegated marls of the Trias, that most rock-salt occurs. An idea that all rock-salt was referable to that epoch long prevailed amongst geologists; but it is now generally admitted that, although salt is found most abundantly amongst Triassic rocks, and becomes rarer as we descend into the earlier strata, it occurs in all the so-called sedimentary rocks. It has not yet been found in granite, nor in any of the crystalline truly so-called primary rocks. In the N. counties of England, are frequent occurrences of brine-springs rising from the Carboniferous series. The Cheshire and Worcestershire deposits are considered by some to belong to the Permian, though most generally they are referred to the Trias. The salts of W. New York, and Goderich (Canada) are said to be of the Salina period of the Upper Silurian. The deposits of the Vosges, Salzburg, and numerous others are generally admitted to belong to the Trias; that of Bex in Switzerland, to the Lias; those of Wieliecska in Poland, and Cardona in Spain, as also some deposits in Algeria, are considered to be Cretaceous; those of the Pyrenees, in the neighbourhood of Bayonne and Dax, and at Camarade, are probably Tertiary; while the Dead Sea, Lake Elton, many other inland lakes, certain estuaries on the shores of the Caspian, the Limans of Bessarabia south of Odessa, the run of Cutch, and the bitter lakes of the Isthmus of Suez, are instances of salt deposits now in actual progress. The last-named lies in a basin which was intermittently inundated by the Red Sea, the waters being evaporated, and beds of salt thrown down, between the successive incursions. At the time the Suez Canal was made, the formation was partially destroyed. Its layers are said to vary in thickness from 1½ to 7½ in., and it is estimated to contain 97 million tons of salt, and to cover an area of 66 million sq. yd. The oldest deposit of rock-salt known to exist, whose geological age may be said to be positively determined, is the Salt Range of the Punjaub, which may with tolerable certainty be referred to the Permian, while the deposits lately discovered at Middlesborough-on-Tees may also probably be referred to this period, as they immediately overlie the magnesian limestone.

Thomas Ward and Von Baer describe the salt formation now going on upon the shores of the Caspian. As at this part it fills with river deposits, a number of bays and gulfs become nearly separated from the main body of the sea; when this occurs on the eastern side, where no rivers enter, and where the evaporation is great, these bays and gulfs soon become intensely salt. Near Novo Petrovsk, on the eastern coast, is a number of basins, presenting every degree of saline concentration. One of these still occasionally receives water from the sea, and has deposited on its banks only a very thin layer of salt. A second, likewise full of water, has its bottom hidden by a thick crust of rose-coloured crystals, like a pavement of marble. A third exhibits a compact mass of salt, in which are pools of water, whose surface is more than a yard below the level of the sea. A fourth has lost all its water by evaporation, and the stratum of salt left behind is now covered by sand. Here we have an instance of what must have frequently happened in the drying up of seas. On the same coast of the Caspian, is the Kara Boghaz, an estuary of considerable extent, and nearly separated from the main body of the sea by a bank, through which there is a shallow inlet. The evaporation from the surface of this gulf is so great that a current continually sets in to it from the main body of the Caspian, and as there is no return current, the water of the gulf is daily becoming more saline, and a salt deposit is being formed, which Von Baer estimates at the rate of 350,000 tons a day. Schleiden says that the Caspian is deprived of nearly 450,000 tons daily by this current, which rather increases the quantity; Von Baer's estimate would give 127,750,000 tons per annum. These figures seem exaggerated, in face of the composition of the Caspian. For every ton of salt conveyed in, there must be 99 tons of water. In process of time, this large gulf will be cut off from the Caspian, and gradually leave enormous beds of salt. On the N.-W. of the Caspian, but some 200 miles from it, are the remains of a similar gulf, Lake Elton, from which large quantities of salt are annually obtained. In 1805, Göbel bored at a distance of about 1⅓ miles from its then shore, and found 42 distinct layers of rock-salt, the uppermost 4 in. thick, the lowermost 9 in. The deeper he went, the purer and more solid was the salt; at the 100th layer (1 ft. thick), it was so hard that the iron tool broke. In time, Lake Elton will disappear like so many others, and its salt will become covered by sand and soil.

The stratified nature of all salt deposits with their interposed beds of clay, the salt rock itself generally possessing a perfectly stratified structure, as well defined as any other rocks of known aqueous origin, points also to the fact that rock-salt must have been deposited from solution. The large quantity of selenite (crystallized hydrated calcium sulphate) so constantly found interstratified and intimately mixed with rock-salt is in itself an almost conclusive proof of its marine origin, for selenite is a hydrated mineral, losing its water at a temperature far inferior to that at which sodium chloride fuses; thus crystals of selenite could hardly have found their way into the solid mass of the salt unless they had been deposited from solution simultaneously with the salt itself. In subsequent times, should the surface of the mixed bed be denuded or dissolved by the action of water, the salt would be carried away, leaving a bed of gypsum, such as is constantly found overlying and surrounding rock-salt deposits. In some districts, as those of Magdeburg, Stassfurt, Vic, &c., beds of potassium and magnesium salts are found overlying the rock-salt. Sea-water contains similar salts, which on its being slowly evaporated are deposited in the same order as and in similar forms to those found in connection with these German salt formations. Supposing the existence of a great Triassic estuary or lake becoming in the lapse of ages completely dried up, it is easy to imagine how the formation of these German deposits took place. Beds of salt would be found, while the inland sea from which they were produced would become continually enriched with successive accessions of salt washed by floods from the salty soil of the surrounding country, and streams would also bring down clay and mud, so that in course of time layers of salt would be formed interspersed with beds of clay, and they might ultimately become covered up and protected by this same clay deposit. In this upper bed of clay, beds of the more soluble potassium and magnesium compounds would remain interstratified.

It has been urged that little or no potassium salts occur in some of the best-known rock-salt deposits; most rock-salt formations, however, show evident traces of denudation subsequent to their formation, as attested by the rounded and waterworn appearance of the exterior surfaces of these beds, indicating that they have undergone superficial re-solution before becoming finally protected by their clay covering. Any denudatory influence of water would first tend to carry off the more soluble potassium and magnesium salts overlying the rock-salt, and only subsequently to this would it attack and dissolve part of the rock-salt, leaving it with a covering of the less soluble gypsum, as already explained. Reniform masses of rock-salt embedded in clay, similar to the larger masses found in nature, may be observed on a small scale in the bottoms of tubs used for dissolving rock-salt. It is perhaps difficult to imagine the enormous lapses of time required in the production of some of the great salt masses. The salt-beds of Cheshire are 75–110 yd. thick in many parts; those of N.-E. France, about Nancy, 7 layers in all, separated by beds of clay, occur at 65 yd. from the surface, and have been proved to be more than 13 yd. deep of salt; those of S.-W. France, at Dax, have been pierced to a depth of 163 yd., without reaching their limit. Whole mountain masses in some countries are largely composed of salt; in Germany, rock has been penetrated to a depth of 1390 yd., of which, all but 94 yd., was in rock-salt. The whole question is one of time, and geologists are daily becoming more accustomed to deal with questions on this basis. It is, indeed, a fact that if the whole of the known deposits of rock-salt in the world were to be added to the waters of the ocean, they would but raise its standard of saltness to an insignificant extent. It has been shown by eminent physical geographers that the surface of the ocean possesses a total area of no less than 132 million sq. miles, allowing 97 million for the Pacific and Indian Oceans collectively, and 35 for the Atlantic Ocean. The quantity of rock-salt which the sodium chloride contained in the waters of the entire ocean could produce, on a basis of an average depth of the ocean of 3 miles (or a bulk of 396 million cub. miles), and assuming 1 gal. of sea water to contain about 0·2547 lb. of salt, and taking 2·24 as an average sp. gr. for rock-salt, 1 cub. mile of sea water would contain such a quantity of salt as would produce 0·01116 cub. mile of rock-salt, which, multiplied by 396 million, gives 4,419,360 cub. miles as the bulk of rock-salt that the evaporation of the entire ocean would yield. This very large figure is equal to 14¼ times the cubic contents of the continent of Europe. It is therefore obvious how little the salinity of the sea would have been decreased by the abstraction of such a relatively small quantity of salt as that collectively contained in all the known rock-salt deposits.

It is remarkable how frequently erupted rocks and hot springs are found in the neighbourhood of salt deposits; but this need not be taken as pointing to a volcanic origin for the salt itself. A specimen of salt erupted from Vesuvius in 1822, analyzed by Laugier, gave the following composition:—Sodium chloride, 62·9 per cent.; potassium chloride, 10·5; silica, 11·5; sodium sulphate, 1·2; calcium sulphate, 1·1; ferric oxide, 4·3; alumina, 3·5; lime, 1·3; loss and moisture, 3·7. The very large proportions of potassium and silica distinguish this from any known rock-salt. It is but fair, however, to observe that, on other occasions, considerable quantities of nearly pure sodium chloride have been emitted from this mountain.

It is easy, on the other hand, to understand how depressions and elevations produced in the earth's crust by disturbances due to volcanic phenomena would tend to the formation of estuaries and inland seas favourable to the production of salt; and many such disturbances and eruptions probably occurred during the time when the ocean bed was being raised and became dry land. Further it is to be noted that most trappean rocks are rich in iron, often ferric sulphide, whilst they are easily disintegrated by the combined influences of moisture and atmospheric oxidation. Salt itself assists in promoting such decompositions, so that islands or cliffs of trap on exposure would tend to crumble down and decompose, and under the action of the briny waves of such a sea, some of the iron present might temporarily dissolve as ferrous sulphate, accounting for the frequent red colour of rock-salt. Any sulphur combined with the iron would be oxidized to sulphuric acid, and go to augment the gypsum derived from the sea-water by combining with lime from the surrounding strata, while the crumbled trap, subsiding as clay, and becoming interstratified with gypsum, would wrap up the salt in a protective covering, and preserve it from re-solution.

Another noticeable and not easily accounted for feature in the geology of rock-salt is its frequent association with bitumen and petroleum, which are found with salt in the oil formations of Pennsylvania. Bastennes, where bitumen was long worked, is close to the salt deposits of Dax, at the foot of the Pyrenees; and petroleum floats in small quantity on the surface of a spring near Orthez, and has been found in a boring in the neighbourhood of Salies in the same district. Petroleum and bitumen also occur not far from Volterra in Tuscany, where the largest rock-salt works of Italy exist, and near to which are Count Larderel's celebrated boracic acid springs; and they are worked in some quantities in Wallachia, where also much rock-salt is found. Petroleum has lately been discovered in Hanover, not far from the German salt deposits already mentioned. Bitumen colours the lowest beds of the rock-salt mines of Nancy. It is found in and around the Dead Sea in numerous places, while both bitumen and petroleum occur abundantly at Baku, on the Caspian, near some large salt deposits both old and recent. A good deal of organic matter, both vegetable and animal, exists in the sea, and as its waters became concentrated, such organic matter would concentrate with them. Large quantities of shells filled with petroleum are spoken of as being found in Pennsylvania, and myriads of shells saturated with bitumen occur in the old workings of Bastennes; but whether or no there is any tendency of organic matter in presence of strong brine, through the avidity of brine for water, to develop itself into these hydrocarbons, remains for the present a mystery unsolved. Such a union of facts as here given testifies strongly to the theory that rock-salt is a true sedimentary rock, and that it probably owes its origin to the slow evaporation, in the course of enormous lapses of time, of salt lakes or inland seas fed from the waters of the ocean. The sea as it now exists may owe some of its saltness to the solution of rock-salt formed during previous geological periods, and subsequently depressed beneath the present ocean. Probably such cases of solidification and re-solution have been frequently repeated, but that the present known formations of rock-salt owe their origin to an evaporation of salt water, such as is now going on in certain quarters of the globe, rather than to any eruptive agency, there can be hardly any room to doubt.

The very general distribution of salt in almost every known region of the globe, the facility with which it can be quarried from the mountain sides, or obtained by evaporation from the waters of the sea, or of salt lakes, the fact of its being a prime essential in the economy of life, and a staple raw product of numerous important industries, have led to the introduction of the salt manufacture in one form or other into almost every country, and shed an interest over all facts connected with its production. In considering the various processes by which salt is manufactured, the methods employed in European countries will alone be studied, especially comparing the English manufacture with those in use abroad, where important differences exist. The subject will be divided into 3 heads:—(1) The production of salt from sea-water by spontaneous evaporation; (2) the mining of rock-salt; (3) the production of white salt from brine by evaporation with artificial heating.

Sea-Salt or Bay-Salt (Fr., *Sel marin*; Ger., *Meer-salz*).—The production of salt from sea-water by spontaneous evaporation varies much with the general atmospheric conditions. It was at one time practised in England; at Lymington in Hampshire, at Hayling Island near Portsmouth, and at Saltcoats on the Ayrshire coast, the evaporation of sea-water for the production of salt in "salterns" or "brine-pans" was formerly a staple industry. Since the suppression of the duty on salt, and the development of the production in Cheshire and Worcestershire, the sea-salt industry has been reduced to one or two establishments round the coast where coal is cheap, as at N. Shields, where salt is made by artificial evaporation from strong brine produced by dissolving rock-salt to saturation in sea-water. But the employment of solar heat is common in countries where the climate is more suitable; hundreds of thousands of tons of salt are annually produced in this way along the W. shores of France and Portugal, in the Bay of Cadiz, along the E. of Spain and S.-E. of France, and along the coasts of Italy, Austria, Greece, Turkey, and Russia. The manufacture of salt from sea-water is in fact an industry of high importance, employing much labour, and affording large revenues.

Sea-water differs but little in its composition, whether taken at the surface or at the lowest depths, tides and currents apparently maintaining it in a perfect state of mixture. Some enclosed seas, such as the Red Sea and the Mediterranean, appear to be rather richer in saline matter than the waters of the ocean; others, as the Black Sea and the Baltic, are somewhat poorer. Under the tropics, and where dry winds prevail, there is some trifling augmentation of the saltness of the ocean, whilst at the poles, and near the mouths of some great rivers, the water is rather less salt, but these differences are completely local and relatively insignificant. Table I. (opposite), gathered from various authorities, though it may be considered fanciful in respect of the combinations in which the various elements are supposed to exist, will convey an idea of the composition of sea-waters.

For the better understanding of the processes of manufacturing sea-salt, it will be convenient to consider what are the general results of the concentration of sea-water by evaporation. Usiglio, in some observations very carefully made in the neighbourhood of Cette upon the water of the

Mediterranean during evaporation, describes the reactions and the order in which they take place. The sp. gr. of the water there is 1·023. When the clear water is submitted to concentration by evaporation, no deposit takes place until the water attains a sp. gr. of 1·05, when a little ferric oxide and calcium carbonate begin to go down. This continues till the sp. gr. is 1·12, at which point, selenite (hydrated calcium sulphate) also begins to separate, and continues till the sp. gr. is 1·25. Meanwhile, as soon as 1·21 is reached, i. e. when the original volume of the water is reduced from 1000 parts to 95, magnesium sulphate crystallizes out with the selenite, accompanied by some sodium and magnesium chlorides. Sodium bromide likewise begins to deposit so soon as 1·231 is attained. The precipitation of these 3 salts continues steadily to progress until close upon sp. gr. 1·3, and the volume of the solution is reduced to 16 parts, or about $\frac{1}{63}$ of what it was. Its percentage composition will then be :—Magnesium sulphate, 11·45 per cent. ; magnesium chloride, 19·53 ; sodium chloride, 15·98 ; sodium bromide, 2·04 ; potassium chloride, 3·30 ; water, 47·7. So that when the water had only reached a sp. gr. of 1·21, the only substances which had separated were (in percentages of the original water) :—Ferric oxide, 0·0003 ; calcium carbonate, 0·0117 ; selenite, 0·1466 ; but between 1·21 and 1·231, the composition of the deposit became :—Calcium sulphate, 0·0283 ; magnesium sulphate, 0·0621 ; sodium bromide, 0·0222 ; magnesium chloride, 0·0153 ; sodium chloride, 2·7107. Thus between these two last-named densities, nearly 2·84 per cent. of saline matter crystallized out of the solution, 95½ per cent. of this being sodium chloride.

These results are most instructive, and their application in the art of salt production from sea-water will presently be seen. Usiglio further describes the reactions which follow on continuing the evaporation of the mother-liquor ; how they become more complicated, and the composition of the material which salts out commences to vary with alternations of temperature ; how, if the temperature of this mother-liquor of sp. gr. 1·3 be lowered, as by exposure during the night, magnesium sulphate alone will crystallize, whereas if the liquor be concentrated by further evaporation during the day, a mixture of sodium and potassium chlorides with magnesium sulphate goes down. By this deposition, the solution slightly loses in density, and its sp. gr. may possibly fall to about 1·28. Magnesium bromide also separates with the potassium and magnesium chlorides, and a double potassium and magnesium sulphate forms, corresponding with the kainite of Stassfurt ($K_2SO_4MgSO_46OH_2$). There likewise separates another double salt, corresponding to the Stassfurt carnallite (potassium and magnesium chloride, $KClMgCl_26OH_2$). Finally, the mothers, which now have attained a sp. gr. of 1·333, retain scarcely any sodium chloride or magnesium sulphate, very little potassium chloride, and are in point of fact a saturated solution of nearly pure magnesium chloride. This last salt crystallizes if the temperature be lowered to about 4½° (40° F.).

TABLE I. COMPOSITION OF SEA-WATERS.

LOCALITIES.	English Channel.			Atlantic.		Mediterranean.		North Sea.	Caspian Sea.	Black Sea.	Dead Sea.
AUTHORITIES.	Riegel.	Schweitzer.	Laboulaye.	Ure.	Boullion, Lagrange et Vogel.	Laurent.	Ann. de Ch. and Ph., Sept. 1849.	Clemm.	H. Rose.	Gobel.	Fleck.
CONSTITUENTS.											
Sodium chloride	2·4632	2·7060	2·50	2·789	2·510	2·722	2·9424	2·484	0·754	1·4019	7·405
Potassium chloride ..	0·0307	0·0765	..	0·154	..	0·001	0·0505	0·135	..	0·0189	1·690
Magnesium chloride ..	0·2564	0·3666	0·35	0·233	0·350	0·614	0·3219	0·242	..	0·1305	12·811
Calcium chloride	0·0439	..	..	..	..	..	..	..	..	..	3·536
Magnesium bromide ..	0·0147	0·0030	..	..	..	..	..	..	..	0·0005	..
Sodium bromide	..	..	..	0·052	..	..	0·0556	..	..	..	0·502
Calcium sulphate	0·1097	0·1406	0·01	0·155	0·015	0·045	0·1357	0·120	..	0·0105	0·121
Magnesium sulphate ..	0·2146	0·2300	0·58	0·184	0·578	0·702	0·2477	0·206	0·406	0·1470	..
Sodium sulphate	..	..	..	..	..	..	..	..	0·036	..	1·217
Calcium carbonate	0·0176	0·0030	0·02	..	} 0·020	0·020	{ 0.0114	..	0·018	0·0365	..
Magnesium carbonate ..	0·0078	..	..	..			..	..	0·440	0·0289	..
Ferric chloride	..	..	..	..	..	..	0·0003	..	..	..	..
Water	96·8414	96·4743	96·54	96·433	96·527	95·896	96·2904	96·813	98·346	98·2253	73·926
Total..	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·
Percentage of solid constituents	3·1586	3·5257	3·46	3·567	3·473	4·104	3·7655	3·187	1·654	1·7747	26·065

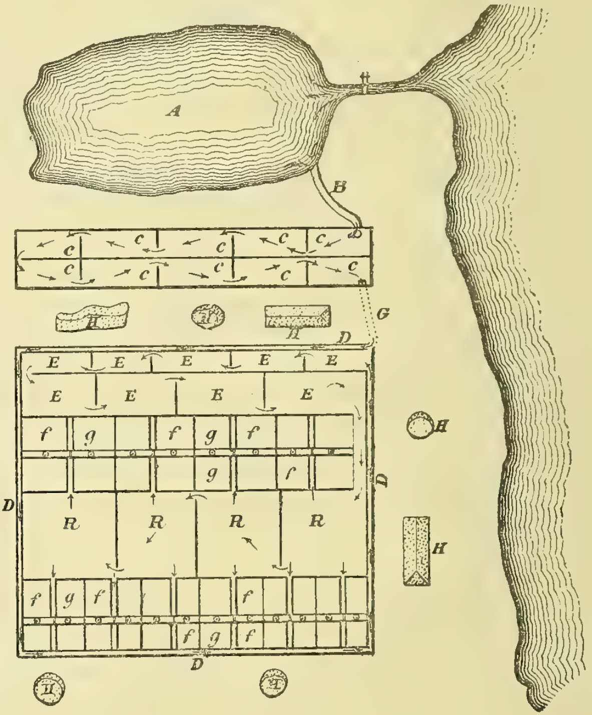
The works in which the sea-salt industry is carried on consist of several series of basins communicating with one another, and possessing extensive evaporating surfaces. Through these, the sea-water is led until arriving in the last, which are very shallow ; the already concentrated salt water is allowed to stand till most of the salt has crystallized out.

The mother-liquor or "bittern" is drawn off, and the salt is collected and drained to dryness. The first of the series of basins is usually a large shallow pond, into which the sea-water is admitted, and where it is allowed to settle, and is stored for use. Sometimes two such large basins are employed, one for settling, the other for storage. Hence the water is carried through a series of other basins, each set in its turn being smaller and shallower. In the last, the salt principally deposits; it is then collected, drained, and stacked for sale.

These works are called by various names, according to the countries in which they are situate. In England, they were known as "salt-marshes," "salterns," "salt-gardens," and by other local names. In France, they are called *marais salants* or *salins*; in Portugal, *marinhas*; in Germany, *Meersalinen* or *Salzgärten.*

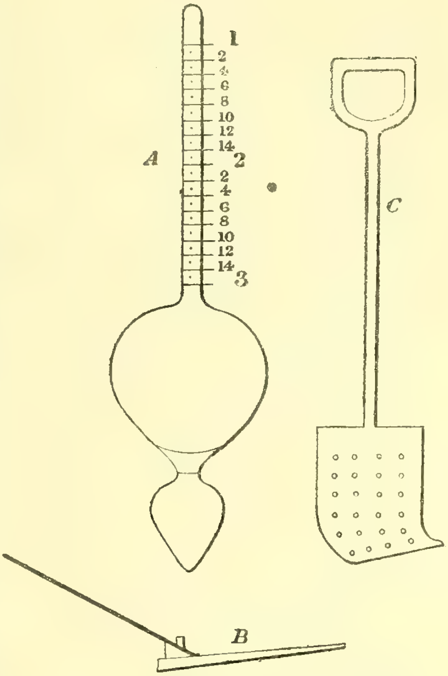
Fig. 1203 shows a *marais salant* as now in use on the Atlantic coast of France. The spot chosen is generally some little bay or creek protected from the direct action of the waves; from this, is led a small canal, through which at spring-tides the sea-water can be conducted into the large reservoir A, the *jas* or *vasière* ("settler"), where the water is allowed to clarify. This reservoir is usually placed higher than the rest of the *marais salant*, so that the water can be run off at pleasure into the first set of basins or *couches* c, without pumping. The *jas* may be of any moderate dimensions, and often covers 2¼ acres, the depth varying from a yard to a fathom. The water, having become thoroughly clarified in the *jas*, is allowed to run by the underground channel B, fitted with a suitable sluice, to the *couches*, which are frequently about 23–24 ft. long, 12 ft. wide, and 1–1½ ft. deep, arranged in sets of 8 or 10 in a double row, as shown, separated by low walls or dams, but communicating with each other in such a manner that the water entering from A by the sluice B can circulate slowly through them, as shown by the lines and arrows, and be drawn off by the sluice G. In fine weather, the water has already undergone some degree of concentration by the time it has settled in the *jas* A, and as it passes in an almost insensible current through the *couches*, it continues to evaporate. It is led by the sluice G into a canal D, which nearly encircles the *marais salant*, and serves to conduct the water on to the *tables* E, arranged similarly to the *couches*; over these, it flows as before in an almost insensible current into other basins R, called *adernes* or *muants*, whence it is fed as required by small channels cut in the soil into the *œuillets f g*, small basins where the salt crystallizes, or, as the French peasants say, "*où l'eau commence à saliner.*"

1203.



On the shores of the Mediterranean, about Cette, Marseilles, and the Étang de Berre, immense quantities of salt are produced by a somewhat similar arrangement. As, however, there are no tides in that sea, the arrangement with the separate reservoir A is not essential. A series of basins, whose bottoms are levelled and pugged with clay, are made by sets in gradients (usually 3) so arranged with channels and sluices that the water can flow from basin to basin and from one set to another. The general principles involved are much the same as on the Atlantic coast. They differ, however, in the degree of circulation of the water. In the western works, the water is allowed to almost stagnate, as it were, no differences of level being maintained so as to promote its flow, except in respect of the *jas*, which is usually placed on a rather higher level. In the *salins du midi*, on the contrary, when the flowing water has reached its lowest gradient, it is collected in large wells, whence it is drawn up and thrown back by a pump or water-wheel to its former level, and again traverses a like set of gradients, to return once more to another set of wells. The first set are called "wells of green water," the second are called "salt water" wells. On arriving at these latter, the water should have attained a sp. gr. of 1·18–1·20, and be nearly at crystallizing-point. By this means, a greater circulation is maintained, and the evaporation is more rapid. Each set of basins in each gradient is made a little smaller than the previous set, to correspond with the diminishing bulk of the water as it undergoes evaporation. Finally, in a set of basins placed at the lowest level of all, the salt crystallizes; these are called *tables salantes* or *crystallisoirs*, and receive the water so soon as it has attained a sp. gr. of 1·95–2·00. In the salt marshes of the west, the mother-liquor ("bittern") is always left in the *œuillets*, and has a tendency to render the salt rather bitter and deliquescent, by reason of contamination with magnesian salts. In the *salins du midi*, as the French Mediterranean works are called, the bittern is drawn off, and stored in special reservoirs, with a view to its subsequent further evaporation, alternated with refrigeration, for the extraction of the potassium and magnesium salts. When the salt has formed in the *œuillets* or on the *tables salantes*, as the case may be, more ready-concentrated water is run on, the bittern being drawn off in the case of the *salins du midi*, or left in the *marais salants* of the west. Here the water is maintained at a depth of 3–4 in., and a fresh supply is run in every 2 days or so during fine weather, and when enough salt (say 3–4 in.) has accumulated, it is collected by means of a sort of scoop or hand plough B, Fig. 1204, which the *saulnier*, as these workmen are called, pushes along before him. Notwithstanding that he does this work with surprising dexterity, he never fails to pick up a considerable portion of clay with the salt, rendering the latter impure. Of late years, a species of moss has been introduced from the Portuguese marshes into the *salins du midi*. This is grown under fresh water, with which the basins are flooded for the purpose, and forms a clean bed, whereon the salt crystallizes, and is thus obtained far whiter and purer. The salt of the French Atlantic coast often contains not over 88 per cent. of sodium chloride; the Marseilles and Cette salt, over 95 per cent. The salt, after collection, is stacked in heaps H around the *marais salant*, these often being thatched over for protection from rain, and it there drains and loses much of its deliquescence and bitterness by long exposure to the atmosphere. In France, this work lasts in fine summers from April till September.

1204.



The sea-salt trade is far more prosperous on the Mediterranean than on the Atlantic sea-board, for not only is the salt far purer, but less rain falls in the former locality, and that part of the Mediterranean coast bordering on the Gulf of Lyons is very subject to a dry parching wind called the mistral, which, though a great disadvantage to the other inhabitants of the country, blows much profit to the salt-makers. Nobody can imagine more miserable creatures than the poor *saulniers* of the W. coast of France; clothed in rags and more than half starved, pale and shivering with ague, they still struggle to maintain an industry which is gradually dying out. The pan-salt of the S.-W. works of Dax, Salies, Briscous, and Villefranche is competing with them on the one hand; while the more successful *salins du midi* are now able with improved means of communication to bring their salt, which is both better and cheaper, into the markets of their western competitors at Bordeaux, Agen, Perigeux, and Pau; and the salt of the N.-E. of France has driven them from Paris. Looking at the condition of the people, it is little to be desired that this industry should last in the W. of France, and it is much to be wished that they should turn to other employment.

The sea-salt industry of the coast of Portugal is very extensive, that relatively small country producing annually 250,000 tons, of which the salt-works of Sertuval alone yield 150,000 tons. In the districts of St. Ubes, Alcacer do Sal, there are over 400 sets of sea-salt works; and at Aveiro, Figueras, and Oporto, are others of very great importance. In Istria, the sea-salt works of Pirano and Capo d'Istria yield annually 60,000 tons, while the "gardens" cover an area of 9 million sq. yd. In Sardinia, 50,000–60,000 tons of sea-salt are annually produced near Cagliari; while for the rest of Italy, Trappani, Lungro, Cervia, Margherita de Savoia, Comachio, etc., yield 105,000–

120,000 tons. Spain, in the salt marshes of the Bay of Cadiz, Marbella Roquitas, Guandamar, and in the Balearic Islands, produces some 300,000 tons. In Russia, very large quantities of sea-salt are made in the Limans of Odessa, on the shores of the Crimea, and on the N.-E. coast of the Caspian.

The production of sea-salt in France is shown in the table on p. 1737.

The manufacture of sea-salt would appear to be a profitable concern in the Eastern Archipelago. The following is an estimate of the cost of carrying on the manufacture at the salines of Baria. The space allowed for the tables is about 40 per cent., the beds 40, and the *jas* 20. To establish 200 acres of "tables," requires no less than 250 acres of land. The working of 1 acre of tables, or 2½ acres of saline, involves the following expenditure:—1500 *fr.* for feeding the workmen during the formation of the salines; if the first collection of salt is good, the workpeople are paid a second sum of 1500 *fr.*, and the collection of salt is given over to them for their own benefit. The capital thus advanced amounts to 3000 *fr.* The second year the proprietors work on their own account, and may collect salt to the value of 2000 *fr.* After deducting tax, etc., there remains about 1200 *fr.* of net revenue on the capital advanced at different stages (3000 *fr.*), or about 36 per cent.

In India, where the Government monopolizes the sale and manufacture of salt, the annual consumption during the years 1867–8 amounted to 22,700,000 *maunds* (of 82¼ lb.), in 1878–9, 24,200,000 *maunds*. The duty varies from 1*s.* to 6*s.* 6*d.* a *maund*. The bulk of this salt is obtained from the evaporation of sea-water or from the Sambhur Lake, but the output of Punjab rock-salt was in 1878–9 estimated at over 600,000 *maunds*. The quantities of white salt sent to India from this country will be seen on p. 1736.

Extensive salt fields exist at Shimpaga, a short distance above Mandalay, on the W. bank of the Irrawady. It is also obtained at other places in Burma on a small scale. Large quantities could be manufactured at Shimpaga, but imported salt is fast taking its place in the market.

Table II. shows the compositions of some of the sea-salts known in the markets of Europe:—

TABLE II. ANALYSES OF SEA-SALTS FROM WELL-KNOWN LOCALITIES.

LOCALITY.	St. Ubes.						St. Martin.	From Brittany, Marais Salants de l'Ouest.	Island of Oleron.	Salins du Midi.	Cadiz.	St. Felice Trappani.	
AUTHORITY.	Henry.	Berthier.		Karsten.			Henry.	Enquéte sur les Sels.	Henry.	Enquéte sur les Sels.	Watts.	Schrotter and Pohl.	
CONSTITUENTS.													
Sodium chloride	96·00	95·19	89·19	95·86	92·46	96·50	95·95	87·97	96·40	95·11	92·11	95·91	96·50
Magnesium chloride ..	0·30	..	..	0·24	0·55	0·32	0·35	1·58	0·20	0·23	..	0·46	0·50
Magnesium sulphate ..	0·45	1·69	6·20	0·35	0·66	0·25	0·60	0·50	0·45	1·30	0·99	0·40	0·51
Sodium sulphate	..	..	..	..	..	..	..	..	..	..	..	..	..
Calcium sulphate	2·35	0·56	0·81	1·30	2·28	0·88	1·90	1·65	1·95	0·91	0·33	0·49	0·45
Water	..	..	0·20	2·10	3·10	1·95	..	7·50	..	2·35	6·30	2·58	2·42
Insoluble matters.. ..	0·90	2·45	3·60	0·15	0·95	0·10	1·20	0·80	1·00	0·10	0·27	0·16	0·07
Loss..	..	0·11	..	..	..	..	..	..	..	..	..	..	..
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

There is one other method of salt manufacture employed in countries where extreme cold prevails, and which deserves passing mention. When sea-water is frozen, fresh water alone congeals, and the residue is a highly concentrated solution of its saline contents. This solution, further concentrated by evaporation, yields crystals of common salt. In the Russian province of Okhotsk, this industry is carried on to some extent during the winter months, but to judge from the annexed analyses by Hess, the salt so obtained is not of superior quality:—

	1st crystallization.	2nd crystallization.	3rd crystallization.
Sodium chloride	86·0	79·1	77·6
Aluminium ,, ...	3·6	7·8	6·2
Calcium ,, ...	0·9	0·7	0·9
Magnesium ,, ...	2·0	0·8	1·7
Sodium sulphate	7·5	11·6	13·6
	100·0	100·0	100·0

Salt is also made in small quantities in Holland and some other countries of N. Europe by dissolving rock-salt to saturation in sea-water, and evaporating the solution by artificial heat, as will hereinafter be described under white salt. The salt so obtained is merely for local consumption, and the business is not important enough to merit more than passing allusion.

Rock-Salt (Fr., *Sel Gemme*; Ger., *Stein-Salz*).—The geology of rock-salt has been already pretty fully considered in the commencement of this article. In a paper read before the Literary and Philosophical Society of Liverpool, Thos. Ward gives a classification of the principal rock-salt deposits of Europe, which is deserving of reproduction almost *in extenso.*

The great salt districts of Europe in which rock-salt or brine-springs are met with are:—(1) Carpathians, (2) Austrian and Bavarian Alps, (3) W. Germany, (4) Vosges, (5) Jura, (6) Swiss Alps, (7) Pyrenees, (8) Spanish or Celtiberian Mountains, (9) isolated deposits and springs in Russia, Turkey, Italy, Prussia, British Islands, &c., and (10) Cheshire, Worcestershire, &c.

1. The Carpathians.—This is the most extensive and rich salt district in Europe, possessing salt enough to supply the whole continent for several thousand years. The Romans mined salt in various parts of Transylvania, and down to the present time salt is obtained from that country. From the extreme west of Galicia, following the direction of the Carpathians to where they meet the Danube, salt is more or less widely distributed on both slopes of the chain. The district may be divided into the Moldo-Wallachian, Transylvanian, Galician, and Hungarian sections.

The salt-mines of Wallachia are very noted, and the salt is distributed by means of the Danube and its tributaries over Bulgaria, Servia, and Hungary, as well as over the home districts. The salt used is the rock-salt, as is generally the case throughout the district of the Carpathians. Owing to the absence of cheap fuel, and the tolerable purity of the rock-salt, very few attempts to manufacture white salt have been made, and millions of gallons of nearly saturated brine are allowed to run to waste. The mines at Stanikul, Kimpina, Okna, and Okna Mare are the most important in Moldo-Wallachia.

Transylvania is richer in rock-salt than any other portion of Europe. It consists of a central basin, that of the Máros river, and the basins of the upper courses of the Számos and Alt rivers. The whole territory is more or less mountainous, and the deposits of rock-salt are frequently found along the banks of the small rivers amongst the hills. The supply of salt is inexhaustible. The great centres of salt-mining are Máros Ujvar, on the Máros river, most favourably situated for water communication, and hence the largest shipping town in the district, exporting seventy per cent. of the Transylvanian salt; Parajd, on the Korond, a tributary of the Máros; Dées Akna, on the Great Számos; Számos Ujvar, on the Little Számos; and Vizakna, on a small tributary of the Máros. The mine at the small town of Sasmezö, in the Ojtoszer Pass, forms a connecting link between the Transylvanian and Moldo-Wallachian districts. The generality of the mines lie near the surface, though the salt is followed downwards to great depths. The quantity of salt mined is very small compared with that in English mines. The whole annual production of Transylvania is estimated at 50,000 tons, about $\frac{1}{8}$ of the production of all kinds of the Austro-Hungarian empire.

The Galician district extends along the N. and N.-E. slopes of the Carpathians, from Moldavia to Moravia. There are numerous mines and brine-springs scattered at intervals along this district. The most celebrated salt-mines in the world, and those longest worked, are the mines of Wieliczka and Bochnia, at the extreme west of Galicia. The mines at Wieliczka have been worked since the 13th century. The mines and works of Sanok, Starasol, Kaluscz, and numerous other places, send out considerable quantities of salt; and recently there has been discovered in the Kaluscz mine, sylvin, or native potassic chloride, and magnesic sulphate.

The Hungarian salt district is very extensive, but almost wholly confined to the region of the Carpathians, from the borders of Transylvania to Moravia. One of the largest tracts lies in the basin of the Számos, in the neighbourhoods of Szathmar and Szigeth, and in the neighbouring districts of Marmaros. In the localities of Soovar and Szlec, in the extreme north of Hungary, there are numerous mines. A continuous series of salt deposits is thus traceable from the neighbourhood of the Alt in Wallachia, along the Carpathians (and the minor chains running from them) around Transylvania, and thence on both slopes of the same mountains between Galicia and Hungary, until the Sudetic mountains are reached.

2. The Austrian and Bavarian Alps.—This is probably the best known salt district of Europe to ordinary travellers. The most important mines and springs lie in a comparatively small area, in the upper parts of the basins of the Traun and Salza, and partially in the basin of the Inn. The most celebrated region is the Salzkammergut, lying on both sides of the river Traun, on the borders of Styria and Salzburg. The salt is chiefly manufactured. In many cases, water is allowed to run into the rock-salt mines, and to become saturated brine, then drained off, and manufactured, many miles away. The district extends into Bavaria, along the valley of the Salza. The most important salt towns in the Austrian portion are Aussee, Ischl, Hallstätt, and Hallein. The Bavarian portion is very rich in salt, the chief towns being Berchtesgaden, Reichenhall, Traunstein, and Rosenheim. The last-named manufactures the salt from brine conveyed in pipes from

Reichenhall. This alpine district extends into the Tyrol; at Hall, near Innsbruck, in the Inn valley, are very extensive salt deposits and salt-works, and the rocks are similar in character to those of the Salza and Traun.

3. W. Germany.—Under this head, are classed a very large number of salt-mines and brine-springs extending from Segeberg, in Holstein, in the north, to Sulz, on the Neckar, in Württemberg, on the south, and from Kreuznach on the Nahe, on the west, to Halle near Madgeberg, on the east. As they are by no means equally spread over the district, it will be well to group them as much as possible. The first group lies in the valley of the Neckar, and one of its chief tributaries, the Kocher. The Black Forest mountains form the west boundary, and the Suabian Jura the east. The chief towns are Sulz, Wilhelmsglück, Hall, Wimpfen, Neckar-Sulm, and Sulzbach. In the valley of the Main and its tributaries, are a few brine-springs. At Hallstadt and Nidda, a large quantity of salt is made; and at Kissingen, is a very strong brine-spring.

The district between the Elbe and Weser contains very large quantities of salt, and springs of brine are met with in great numbers, from the banks of the Werra and Saale, to those of the Aller. The most numerous springs, as also the rock-salt deposits, lie near the various small ranges of mountains that are scattered about the district, as the Thuringer Wald, Harz Mountains, Tentoberger Wald, &c. The most important towns are Salzungen, Allendorf, Halle, Stassfurt, Salza, Schönebeck, Harzburg, Neustadt, Salzgitter, Salzderhelden, Salzwedel, Hildesheim, Rodenberg, Sulze, Luneberg, &c. Closely connected with this district is the Ruhr Valley in Westphalia, in the neighbourhood of Unna, where are numerous brine-springs. Two localities of special importance are the district between Magdeburg and Halle, more especially in the neighbourhood of Stassfurt; and the Luneberg Heath in Hanover, to the south of Hamburg. In both localities, brine-springs have long been known, and Schönebeck and Luneberg have been centres of salt manufacture for a considerable period. It is only of late that the extensive deposits of rock-salt in both neighbourhoods have been discovered. There is one more small district lying quite outside the others, that of Oldesloe and Segeberg, in S. Holstein. At Oldesloe, a brine-spring has been worked for a very long period. It is but within the last few years that rock-salt has been found at Segeberg.

4. The Vosges.—This is a very important district. Its salt meets English salt very extensively in Belgium. Great portions of E., N., and Central France are supplied from it. Until the late Franco-German war, the district belonged wholly to France, but, lying in the ceded district of Alsace-Lorraine (principally in Lorraine), now belongs to Germany, thus rendering Germany the possessor of some of the most extensive salt deposits in Europe. The chief towns in the Vosges district lie in the neighbourhood of Metz and Nancy, and are Chateau Salins, Dieuze, Moyen Vic, Sarrealbe, Salzbron, Rosière. The salt is chiefly manufactured from brine-springs, though a considerable quantity of rock-salt is mined at Vic, and at Varengeville, near Nancy.

5. The Jura.—Since France has lost the salt district of the Vosges, the long-noted one of the Jura will become of more importance. It is separated from that just mentioned by the Plateau of Langres, and lies in the basin of the Saône and Doubs. The salt-springs of Salins have been noted from remote antiquity. The chief centres of manufacture are Salins, Arc, Lous le Saulnier, Montmorot, Saulnot.

6. The Swiss Alps.—This small district lies on the right bank of the Rhone, just before the river enters the Lake of Geneva, in the Canton de Vaud. It has rock-salt mines and brine-springs. The chief centres are Aigle, Bex, and Roche. Rock-salt was mined here 300 years ago.

7. The Pyrenees.—Like the Carpathians, the Pyrenees are rich in rock-salt deposits and brine-springs. In the W. district of the Pyrenees, in both France and Spain, salt appears to be most plentiful. In France, the basin of the Adour is the most important district, and contains the towns of Salies de Béarn, Briscous, Villefranche, which last forms almost a suburb of Bayonne. Dax was discovered accidentally by Ward a few years ago. At Salies d'Arbas, on the Garonne, near the Pyrenees, a brine-spring exists, and salt is manufactured. In Spain, the whole basin of the Ebro is rich in salt, especially towards the source of the river, as is indicated by the number of villages named either *sal* or *salinas*. In one small district, are Salinas, Salinas d'Amana, Salinillas, Poza de la Sal. On the banks of the Ebro, are Mendavia, Valtierra, Remolinos, and Sastag. Both rock-salt and brine-springs are plentiful. One of the most peculiar deposits of rock-salt known to exist is in this district, about 45 miles N.-W. of Barcelona, on the banks of the Cardona river; this is the famous rock-salt mountain of Cardona, a hill composed entirely of rock-salt, which is worked in open quarries like stone.

8. The Celtiberian or Spanish District.—This is rather a number of isolated mines and brine-springs. The chief towns are Saelicas, in the province of Guadalajara; Torreximeno, in the province of Jean; Villafafila, in the province of Zamora; Monteagudo and Minglanilla, in the province of Cuenca; Cazorla and Hinojares, in Andalusia; and Jumilla, in the province of Chinchilla. There are indications of salt in various other places; indeed, Spain seems richly endowed with this mineral.

9. Isolated Salt-Deposits and Brine-Springs.—In France, at the foot of the Alps, at Moutiers and Castellane, are well-known brine-springs from which salt is made. These may possibly belong to the same district as those of Aigle and Bex. In Italy, at Volterra in Tuscany, salt is manufactured; and at Lungro and Altamonte, in the mountains of Calabria, rock-salt is mined. In Sicily, at Nicosia and Mussomeli, are salt deposits. At Szamobor, in Croatia, and Tuzla, in Bosnia, salt is found. In Russia, at Bachmutz, on the Donetz; Balachna, on the Volga; Staraia Russa, near Lake Ilmen; Solikamsk, on the Kama, and the neighbourhood of the Ural Mountains; and at Iletzkaya, salt deposits exist; also at Eupatoria, in the Crimea, rock-salt is found. In Prussia, at Jnowraclaw, Rawicz, Waltersdorf, brine-springs are found; and at Sperenberg, S. of Berlin, a bed of rock-salt, of the enormous thickness of 2810 ft., had been bored into in 1870. At Kreuznach, on the Nahe, rock-salt is mined: this seems to be connected with the Vosges.

10. Cheshire, Worcestershire, &c.—The chief centres of rock-salt and brine-springs are Northwich, Middlewich, Winsford, Sandbach, in Cheshire; Weston-on-Trent, in Staffordshire; Stoke Prior, and Droitwich, in Worcestershire. At Duncrue, near Carrickfergus, there is an important rock-salt deposit. At Middlesborough-on-Tees, another valuable deposit of rock-salt exists. At Chester-le-Street, in Durham, is a brine-spring. Indications of salt are to be met with in Staffordshire, Shropshire, and Lincolnshire. The Cheshire and Worcestershire deposits are by far the most important among British rock-salt deposits, the Carrickfergus salt being only worked to a comparatively limited extent, and the Middlesborough hitherto not at all. This last was discovered some years ago by Bolckow, Vaughan, & Co., while boring for water in their steel-works, but they were unable to follow up the discovery for want of sufficient room. Bell Bros. have now bored in the meadows in front of their works at Port Clarence, where, at a depth of a little over 300 yd., they have again found the salt, and have traversed the bed to a thickness of about 33 yd. No doubt with cheap coal and the facilities for shipment existing at the spot, as well as its proximity to the important industrial centres of the Tyne, the Wear, and the Tees, and its central position on the E. coast of England, the produce of this deposit may some day find its way to the Baltic, and supply part of the Scotch and English fisheries, and figure as an important factor in the salt industry of England.

Rock-salt, as such, is comparatively little worked in England at the present day, only about 115,000 tons being annually sent down the river Weaver, and most of this coming from the celebrated Marston mine, owned by Fletcher and Rigby of Northwich. This is the most extensive rock-salt mine in Great Britain. The rock-salt is mostly exported to Belgium, and some other Continental countries. Germany used to take some rock-salt from England, but since her own discoveries, this trade has greatly diminished. Some consumption of ground rock-salt has sprung up of late, for use in the Hargreaves process of making "salt-cake" (see p. 287), for which it is better suited than the ordinary chemical salt. The rock-salt was first discovered at Marbury in 1670, in trying for coal, and for about a century subsequently only the upper layer of salt was known and worked. As far as the deposits in the neighbourhood of Northwich are known, each is said to consist of two superimposed beds, and to form two separate blocks, about 1½ miles long and 1300 yd. wide, but they are obviously far larger than this. The salt is reached at depths varying from 32 to 53 yd. (at Marston, 37 yd.), by sinking through beds of variegated clays or marls interstratified with layers and nodules of gypsum. The upper bed of rock-salt possesses a thickness of 25–30 yd., but rapidly thins off towards the S.-W. Above this bed of salt, and lying apparently in the recesses of its surface, is found a more or less continuous layer of saturated brine. This is the brine which, extracted at the various pumping-stations of Northwich, Winsford, and other places, and evaporated as described later on, supplies the white salt of the works of these districts. It has obviously been produced by leakages or infiltrations of the surface water through fissures in the superincumbent strata, and this by prolonged contact with the rock-salt has become converted into brine. Once saturated with salt, this brine lies inert upon the rock-salt, producing no further solvent action, until, some of it being withdrawn by pumping, more fresh water flows in from above, or until water, entering the strata at any outcrop which may exist on higher grounds, forces the brine out to the surface as natural springs, and continues the solution of the rock-salt. It is estimated that the quantity of brine pumped in the Cheshire salt districts must in this way annually withdraw not less than 1,122,900 cub. yd. of rock-salt from the subjacent strata, leaving the ground above practically unsupported. In many places, serious damage to property has arisen from this cause, and, in a bill lately attempted to be introduced before Parliament, it was proposed to compensate the losses and destruction of property consequent upon these subsidences by a tax of 3*d.* a ton to be levied on all the salt manufactured in the Cheshire districts; but the bill was rejected. A very exhaustive inquiry was made by a select Committee of the House of Commons on this occasion, which lasted from May 5th to May 20th of the present year, into the geological relations of the Cheshire saliferous strata. Several interesting points were raised as to the causes of the subsidences, and De Rance, of the Geological Survey, among others, afforded some valuable historical and practical scientific evidence, the general conclusions at which he arrived being:—1. That the brine is formed by the natural descent of water through the porous strata of the high grounds surrounding the geological basin of Cheshire on to the saline beds. 2. That the brine so formed passes by gravitation through the strata, emerging from it in several places at the surface of the ground. 3. That this wastage of the saliferous beds has, previously to the interference of man, caused large subsidences in historic times, and is likely still to continue to do so. The evidence adduced with regard to the existence of natural brine-springs and the records of previous subsidences were very interesting, and it seems difficult to imagine how now, after some centuries of working, and in view of the above facts, a tax such as that proposed could be levied on the saltmakers without injustice. One very curious map was placed in the hands of the committee, showing how very large have been the workings in the Northwich region, and that, practically speaking, nearly the whole district is undermined by the excavations for rock-salt, most of these being in the upper bed, and this was held sufficient to account for much of the subsidence in that region. In France, similar accidents have occurred, only to a less extent, from similar causes; and part of the fortifications of the town of Dieuze having been injured by subsidence in the celebrated salt-mines of that place, the waters of the Indre having penetrated into the mines and dissolved the supporting columns of salt, the French Government felt bound to legislate on the matter. The mine of Varengeville, St. Nicolas, also fell in a few years since, causing some loss of life, and considerable destruction of property. Beneath the upper bed of the rock-salt at Northwich, lies one of a kind of greystone, interstratified with veins of salt. This bed of saliferous stone is 10½ yd. thick, and overlies the second or great bed of salt, below which it reappears, and has been sunk into to a further depth of about 62 yd. in another mine adjoining the Marston, where some small layers of salt were found, but of inferior quality. The second bed is the one from which the principal supplies of British rock-salt are now drawn; and at Marston, it has been explored to about 33 yd. in thickness. The Marston mine has been worked for over 100 years, is 120 yd. in depth, and covers an area of about 40 acres. Round the base of the shaft, the roof of the mine is supported by eight huge pillars of rock-salt, each pillar being 30 yd. long by 10 yd. wide. The rest of the mine is equally supported by pillars, between which the salt has been worked out; these are 10 yd. sq., and 25 yd. apart. The main or principal cutting in the mine is called by the miners Piccadilly. The salt is blasted out with gunpowder in the ordinary fashion, and sent up in bens to the surface; the best and purest portions are selected for sale, while those which are too much contaminated with clay are rejected. This description of a rock-salt mine might be repeated for nearly every other salt mine in the world, with the sole difference that in some (as in Wieliczka) the workings are on a more vast and important scale.

The accompanying nomenclature of the strata traversed by the sinking for rock-salt at Witton, near Northwich, shows the position of the Cheshire salt, as given by Holland:—

	Yd.	Ft.	In.
1. Calcareous Marl	5	0	0
2. Indurated Red Clay	1	1	6
3. Indurated Blue Clay, with Sand	2	1	0
4. Argillaceous Marl	1	2	0
5. Indurated Blue Clay	0	1	0
6. Red Clay, with Sulphate of Lime irregularly intersecting it	1	1	0
7. Indurated Blue and Brown Clay, with grains of Sulphate of Lime interspersed	1	1	0
8. Indurated Brown Clay, with Sulphate of Lime crystallized in irregular masses and in large quantity	4	0	0
9. Indurated Clay, Blue, laminated with Sulphate of Lime	1	1	6
10. Argillaceous Marl	1	1	0
11. Indurated Red Clay, laminated with Sulphate of Lime	1	0	0
12. Indurated Blue Clay, laminated with Sulphate of Lime	1	0	0
13. Indurated Red and Blue Clay	4	0	0
14. Indurated Brown Clay, with Sand and Sulphate of Lime interspersed through it. The fresh water, 360 gal. a minute, finds its way through holes in this stratum, and has its level 16 yd. from surface	4	1	0
15. Argillaceous Marl	1	2	0
16. Indurated Blue Clay, with Sand and grains of Sulphate of Lime	1	0	9
17. Indurated Brown Clay, with little Sulphate of Lime	5	0	0
18. Indurated Blue Clay, with grains of Sulphate of Lime	0	1	6
19. Indurated Brown Clay, with Sulphate of Lime	2	1	0
20. First bed of Rock-Salt	25	0	0
21. Indurated Clay or Stone, with veins of Rock-Salt running in it	10	1	6
22. Second Bed of Rock-Salt	36	0	0

The following analysis of the beds of "stone" underlying and intercalated between the beds of salt may be of interest, as a matter of comparison with the composition of pan-scale, and of the deposits formed during the evaporation of sea-water:—

	Per cent.
Water (at 212° F.)	1·86
Loss on ignition (including traces of CO_2)	6·62
Lime (CaO)	3·37
Ferric oxide (Fe_2O_5)	5·80
Alumina (Al_2O_3)	7·85
Sodium chloride	15·60
Potassium chloride	traces
Sulphuric acid (SO_3)	2·16
Phosphoric acid (P_2O_5)	1·95
Insoluble residue:	
Alumina	9·45
Silica	44·51
Total	99·17

The Wieliczka salt-mine, certainly the most celebrated in the world, is situate 9 miles from Cracow in Galicia, and has been worked for about 600 years. It is excavated in the ridge of hills at the N. extremity of the chain which joins the Carpathians. The salt is stoped out in longitudinal and transverse galleries, and large excavations are made in it, forming vaulted chambers of considerable height, and leaving massive pillars with arches between them for the support of the roof; but the work is more of the nature of quarrying than of mining. Explosives are not very generally employed in this or in many of the other salt-mines of the Carpathian district, the rock being cut out in square or longitudinal blocks. Grooves are cut about 25½ in. deep, forming the face of the rock into rectangular divisions; lumps are then broken off from the face of the rock by wedging, and these are further broken up into masses of ½–1½ cwt. for sale. The percentage of lumps to smalls produced by this method is stated to be as 75 to 25, the former selling for about 7*s.* a ton more than the latter. The lumps are generally sold just as they come from the mine, while the smalls are still further ground, and packed in sacks or casks; the scarcity of fuel precludes the possibility of dissolving and refining this salt, while its great purity admits of its easy sale in its natural state. The colour of the rock-salt forming the walls of this mine reminds one of a light-grey granite. The mine is divided into 4 levels or "fields," in the uppermost of which, 34 fathoms below the surface, the packing and preparation for transport is proceeded with. In the lower levels, the work of excavation is carried on; and on the second level, is a lake of fresh water derived from a small stream which flows over the top of the bed of salt, and is carried by wooden shoots to this spot. Many of the chambers in this mine are 80–100 ft. in height, and the excavations have been carried to a depth of no less than 783 ft., while many of the galleries are 1000 yd. long, and the total length of these galleries is about 30 English miles. The mines of Bochnia and Wieliczka together are, however, said only to yield 45,000 tons of salt per annum, the latter counting for 34,000. These mines give employment to 800–1000 miners and other persons. Many books of travel are replete with descriptions of this mine, but visitors who had read the accounts must have been frequently disappointed.

To add descriptions of other salt-mines would be mere repetition, the extraction of rock-salt differing in no respect from the getting of stone in any underground quarry, or the working of coal or similar stratified deposits. Foul air or explosive gases are not usually met with in salt-mines. In the Marston mine, however, after a shot had been fired on one occasion, there was a considerable evolution of marsh gas (methyl hydride), which took fire and burnt for some time, issuing from a blow-hole in the floor. E. Falk also met with a like evolution of inflammable gas in his mine at Winsford. In the strata above the salt in the Dax explorations, a disengagement of marsh gas took place during the sinking of a small shaft, and subsequently during some borings executed at about a mile distant. Some highly compressed pent-up gases, proved to be liquefied hydrocarbons, have likewise been found in small quantities in the rock-salt of Wieliczka and some other places, giving rise to small explosions when the rock is in course of being dissolved. Salt mines are as a rule perfectly dry, and the miners are usually healthy and subject to no special infirmities or inconveniences, unless it be some occasional slight annoyance from the irritating effects of the saline dust entering the throat, eyes, or nose. It is advisable when working a bed of rock-salt to leave a good thickness of the salt under the floor and in the roof, not trusting to the beds of clay with which rock-salt is usually interstratified, and which often exfoliate and give way. The pillars left for the support of the roof should be as large and massive as possible, in view of the possibility, however remote, of their becoming disintegrated and weakened, composed as they are of a soluble, more or less deliquescent material. When a rock-salt working is disposed to give way, cracks and fissures usually appear in the roof, and signs of crushing about the upper part of the pillars.

A process of cutting rock-salt by a stream of water, invented by an engineer named Pletsch, was employed till lately in the mines of Varengeville St. Nicolas, near Nancy. Fresh water, led through a pipe into the galleries of the mine, was there, from nozzles conveniently mounted on movable stands, caused to impinge in fine but forcible jets against the face of the rock. By this means, deep furrows were rapidly cut into the salt by solution, and large blocks could be detached with little manual labour and without blasting. This method, economical though it may appear, seems to have been the cause of a severe disaster in the mines in question. The salt was being worked in one of the lower beds (of which there are seven in all) where it was purest and of best quality, the cutting-water being permitted to run away to a still lower level in a channel cut in the underlying bed of clay, on which, in this case, the levels were driven. This water had a sp. gr. of not more than 1·52, and was consequently far from saturated; the purest portions of rock were therefore selected for sale as rock-salt, and the rest was broken up and used for further saturating the water of the reservoir below. The brine of the reservoir was finally pumped up to be evaporated for white salt. This plan of getting both brine and rock-salt was ingenious, and seemed to work successfully. The workmen, however, had long observed that the galleries of the mine seemed to fill up, by the swelling, as they supposed, of the clay floors, though in reality this was produced by the sinking of the pillars, probably from solution. One day the whole of this part of the mine suddenly fell in, and since then, the getting of rock-salt by this means has been abandoned. Since 1876, a salt-cutting machine has been introduced at Wieliczka with much success. It is constructed somewhat on the principle of Winstanley and Barker's coal-cutting machine. It would appear that in the course of 8 months' working, this machine has shown itself capable of cutting rock-salt horizontally at a rate of 59 sq. ft. per hour, or vertically to a height of 5 ft. 9 in. at a rate of 30–40 sq. ft. per hour. The average cost is stated to be about 21*s.* per cub. yd., as against 27*s.* for hand work. It is likewise stated that in working out the salt, this machine produces less smalls than hand labour, the proportion being only 17 per cent. The machines supplied by Stonek and Reska, of Prague, are made of steel in all their moving parts; they cost about 430*l.* each, and work by compressed air.

The annexed table shows the composition of the rock-salt of a few of the largest and best known mines of Europe. The Stassfurt salt, however, is not generally so impure as stated; in the Paris Exhibition of 1867, the writer obtained a sample from a lot of rock-salt from Stassfurt there exhibited in immense slabs and blocks, which gave on analysis no less than 99·95 per cent. of pure sodium chloride, and 0·05 of calcium sulphate, and was consequently nearly pure.

TABLE III. COMPOSITION OF ROCK-SALTS FROM WELL-KNOWN LOCALITIES.

COUNTRY.	Germany.								France.	Austria.		England.	
LOCALITY.	Schwabisch Hall, Wurtemburg.		Berchtesgaden, Bavaria.	Stassfurt, near Magdeburg.	Château Salins, Lorraine.	Vic, in German Lorraine.			Dax.	Hall.	Wieliczka, Galicia.	Rock-salt from Cheshire.	Do. from the Marston Mine, Northwich.
AUTHORITY.	Fehling.		Bischof.	Rammelsburg.	Mathieu de Dombasle.	Berthier.		Cordier.	Maxwell Lyte.	Bischof.	Bischof.	Richardson and Watts.	Crace Calvert.
Sodium chloride ..	99·97	98·81	99·85	94·57	97·05	99·30	97·80	97·45	96·97	99·43	100·00	98·30	96·70
Calcium chloride ..	..	0·02	trace.	..	..	..	..	..	..	0·25	..	..	0·68
Magnesium chloride	..	trace.	0·15	0·97	0·45	..	..	..	0·51	0·12	..	0·05	trace.
Potassium chloride ..	..	..	..	..	..	..	..	..	trace.	..	..	..	trace.
Calcium sulphate ..	0·02	0·11	..	0·89	1·50	0·50	0·30	0·25	0·23	0·20	..	1·65	0·25
Magnesium sulphate	..	..	..	..	trace.	..	..	2·30	..	..	..	..	..
Magnesium carbonate	..	0·15	..	..	..	..	..	..	..	..	..	..	..
Calcium carbonate ..	..	0·16	..	..	..	..	..	..	..	..	..	..	..
Ferric chloride	..	..	..	..	..	..	..	..	0·01	..	..	..	..
Clay or insoluble matters	0·01	0·80	..	3·35	..	0·20	1·90	..	2·28	..	..	..	1·74
Water or loss	..	..	..	0·22	1·00	..	..	..	..	..	..	..	0·63
Total	100·00	100·05	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

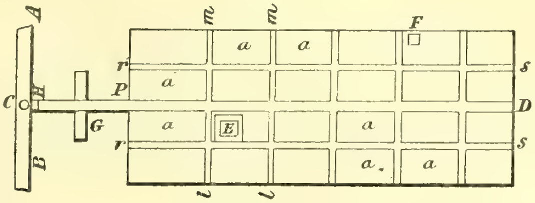
White Salt.—The third branch of the salt manufacture, viz. the production of white salt by the artificial evaporation of brine, is by far the most important of all the methods by which salt is prepared, so far as England is concerned, for not only is the salt thus obtained in a far purer condition than by any other method, but by this method we alone produce in the Cheshire and Worcestershire salt-works, probably as much as a third of the quantity of salt which is consumed in the whole of Europe.

The brine used in Cheshire is that alluded to as overlying the upper layer of the salt-measures, and it is raised by pumping, and fed into the various salt-works. Some of the salt-works raise brine for themselves by their own pumps, only paying a royalty to the landlord. The cost of the brine varies in the different districts: at Northwich, it is 4–9*d.* per ton of salt made; at Winsford, it is 6*d.*, and this latter price may be taken as a fair average. It is rare, however, to find saturated brine thus overlying the beds of salt. In other countries, this is seldom or never the case, and a description of the manufacture of white salt may be commenced by explaining the various methods used for obtaining the strong brine.

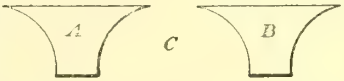
1. A shaft is sunk, and the rock-salt, mined in the usual manner, is brought to the surface and dissolved in water. Sea-water or the water of saline springs is sometimes used. In France, large wooden tubs called *bessoirs* are generally employed. The rock is broken and placed on perforated shelves, or hung in baskets round the upper edges of the tubs. The solution is performed in a reservoir of masonry or of concrete lined with cement, and in this case a sort of wicker boat is sometimes surrounded with empty casks to give it flotation, and laden internally with broken rock-salt, and floated on the water of the reservoir. The salt dissolves, the stronger brine falling to the bottom and the weaker rising to the surface, where it continually meets with fresh salt. The process thus continues, till, if the supply of rock be properly maintained, the whole bulk of the liquid speedily becomes saturated brine.

2. Another method employed, more particularly in working beds of saliferous clay, is the creation of a solution-chamber (*chambre de dissolution*) within the deposit itself (see Fig. 1205), into which water is introduced with certain precautions, and this, dissolving the salt, and becoming converted into brine, is pumped up for use. The construction of such a chamber is carried out in the following manner. A shaft E is sunk to the bed of salt or saliferous clay; in this, a horizontal longitudinal gallery P D is first pierced, and from this, the transverse galleries *l m*, and other longitudinal galleries *r s*; this cuts the beds into squares or rectangles *a*, and these are further divided up by other smaller galleries, not shown, till the whole part to be excavated is cut into galleries, the roof being supported by the pillars left between. The size of the chamber, the distances separating the galleries, their height, &c., must depend on the nature of the ground, and in some degree on the fancy of the operator. By this means, is made a chamber of more or less rectangular form, the central gallery P D running throughout its entire length. Another transverse gallery A B is pierced in the same level, and at some yards distant from the end of the chamber, and the gallery P D is prolonged to meet A B at C. A long wooden pipe is laid from C to D, pierced with holes in its sides and bottom, and its upper part covered with a pent roof, so as to throw off any materials which may fall on it. A good timber dam is made at G, and well pugged with clay, and a sluice is made at H, by which the brine can be drawn off; F is another small shaft, through which water can flow into the chamber. The gallery A B may serve for any number of such chambers on the same level. All being thus arranged, water is allowed to flow down through F till the bases of the pillars are submerged a few inches. This water is soon converted into saturated brine; it is drawn off by opening the sluice H, and pumped to the surface. More fresh water is let in to a like depth, and finally the bases of the pillars get cut away by solution. Each time fresh water is let in, care is taken that it rises only just far enough to bathe the lower ends of the pillars, which are thus gradually dissolved upwards from their bases, the sides of the chamber becoming likewise excavated and enlarged by solution. This goes on until the pillars become completely dissolved, and the whole becomes one great chamber filled with salt water. Much care is to be observed in controlling the quantities of water fed into these chambers, in which the pressure should be maintained as moderate and unvarying as possible. The fresh water admitted, being lighter than the brine, has a tendency to rise to the surface, and the solution is liable to go on almost entirely at the top of the chamber, the interior of which tends to assume the form of an inverted cone from this cause. This involves loss, and where two or more chambers A B are being worked continuously, the erosion of the salt necessarily takes place in the form shown in Fig. 1206, the portion C remaining untouched. A partial remedy for this inconvenience, constituting the best mode of working, and now usually adopted, is to introduce the fresh water in a small but constant and steady stream at F (Fig. 1205), while the brine is being drawn off in the same continuous manner at H. This method of working saliferous clays is much used in Germany; at Dürrenberg, in Saxony, are 33 of these solution-chambers, each possessing a mean capacity of about 700,000 cub. ft.

1205.



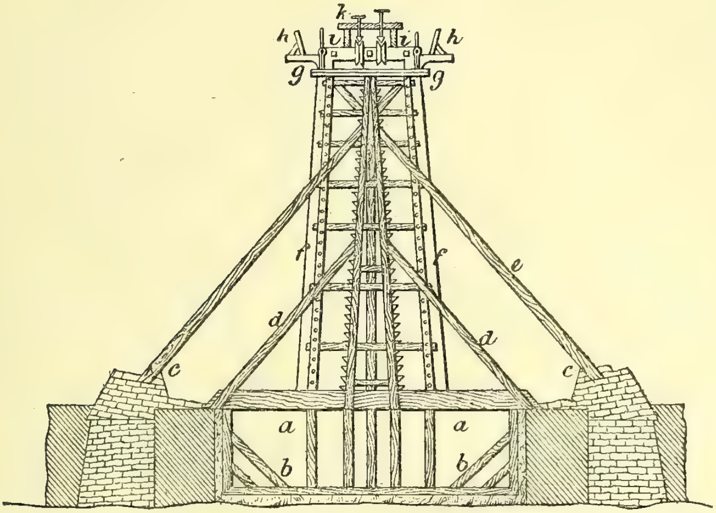
1206.



Another method of obtaining brine from a bed of rock-salt, and one frequently practised in France, is that of simply boring into the salt and letting fresh water run down the bore-hole, when it excavates a chamber for itself in the salt by solution, and may be pumped up again as saturated brine. The boring for this purpose has to be of a tolerably large diameter, say 8–10 in., and it must be tubed throughout with stout, well-riveted iron piping. Within this piping, descends the suction-pipe of a pump, this latter pipe being only 3½–4 in. diam., and closed at the lower end, but having its sides pierced with numerous small holes for about 1–2 ft. from its lower extremity. A sufficient space is thus left between the two pipes for fresh water to find its way down to the bed of salt. It is usual to commence by sinking a well down to any water-bearing strata in the measures above the salt, and to commence the boring only from the bottom of this well; or a well is sunk alongside the boring. Fresh water from the upper strata or the surface is allowed to percolate from this well into the space between the tubing of the bore-hole and the suction-pipe of the pump, and to descend to the salt, where it becomes converted into brine, and may be pumped up. The establishment of a brine-chamber by this means is rather tedious, on account of the tendency of the fresh water to rise to the top, and erosion to take place only at the immediate surface of the salt, which thus gets eaten out just where it meets the superincumbent bed of clay, morsels of which detach themselves, and, falling into the bore-hole, are liable to choke the pump. A year or more may thus elapse before any steady supply of saturated brine can be pumped, much, however, depending on the nature of the bed immediately overlying the salt. If this be clay, much trouble and inconvenience may be experienced; whereas if a good firm bed of gypsum or anhydrite intervenes between the salt and the clay, as occurs in the districts of the Meurthe, all will be found to work successfully. Under these arrangements, the descending column of fresh water in the exterior pipe tending to counterbalance the ascendant column of brine in the suction-pipe of the pump to about ⅚ of its height, the relative sp. grs. being as 1 to 1·20, the pump only has to do the work of elevating the brine through the remaining distance. Thus, with the bed of salt lying at a depth of 180 ft. from the level of the fresh water at the surface, the fresh-water column would tend to counterpoise and elevate the brine in the suction-pipe of the pump to a height of 150 ft., so that the pump itself would only have to lift or force the brine through the remaining 30 ft. In all cases, the brine when produced, whether by dissolving the rock-salt in tubs at the surface, or by extraction from the solution-chamber within the bed of salt itself, contains by far too much matter in suspension to be fit for immediate use. It is consequently allowed to clarify by subsidence in large reservoirs (*bessoirs*) prepared for its reception.

Sometimes the brine, whether derived from springs or otherwise, is not brought to the surface at a sufficient degree of concentration to be evaporated by artificial heat, without too great a consumption of fuel. It then becomes necessary to concentrate the brine. The most economical mode of doing this is obviously spontaneous evaporation by exposure to the air; and in places by the seaside where high winds prevail, and where land may be of but little value, large quantities of salt are economically produced, as already detailed, by this means. But in other places, this arrangement would be inconvenient, and other means of exposing the liquid to evaporation on an extended surface are resorted to. Such is the so-called "graduation" system invented by Abith in the 16th century, and still practised in a few places on the Continent. A graduation-house (*Gradishaus*) is generally a huge shed, 300–400 yd. long, presenting one end to the prevailing wind, and open at both ends. The interior is filled with rows of faggots; the floor is a large flat reservoir or basin, and on the top, by means of pumps and other arrangements, the water is sprinkled profusely over the faggots, and in course of descending into the trough below, trickles over the sticks, and exposes a large evaporating surface. By several repetitions of this process, the liquor loses water, and a concentrated brine is the result. Fig. 1207 represents the general construction of a graduation-house. A description of that at Schönebeck, one of the largest and most important establishments of this kind, will suffice, as the system is not required in England, and is becoming less used elsewhere. The building is 916 yd. long, and 11–14 yd. high. It is filled with a double tier of faggots, presenting a thickness of 5½–7½ yd. at its base, and 3¼–5½ yd. at the top, consequently offering an immense superficies for evaporation. The illustration shows the whole arrangement in profile, end on. *a* is the large reservoir for the salt water. It is excavated in the ground, and widens out at the top to *c* to catch any drip the wind may carry away; *d e* are merely stays to support the walls of the reservoir, and to sustain the building against the lateral pressure of the wind; *f* is the wooden framework in which may be arranged 4 vertical walls or tiers of faggots. These faggots are made of white- or black-thorn, the branches of which are especially crooked and angular. The water is elevated by pumping to the reservoir *h* at the top, which is so arranged that the outflow can be altered according to the way of the wind. The water is allowed to descend through two pipes, closed or opened at will by the valves *k*, into the transverse pipe *g*; thence it rises through the pipes, and flows out by cocks into pans, from the overflow of which it drips on to the faggots. Berthier calculates that the average evaporation in ordinary fine weather by this means at Moutiers, in Savoy, where cords are employed instead of faggots, the other general dispositions remaining the same, is 13⅕ gal. for every sq. ft. of cord surface in 24 hours. At Kissengen, the sheds are nearly 1¼ miles long by 25 ft. high. The water is raised six times in passing from one end to the other of the building, and by this, its strength is raised from 2½ to 17½ per cent. of salinity. Forbes has calculated that here nearly 3 million cub. ft. of water are evaporated annually by this means. The first set of faggots are stained brown by ferric oxide which encrusts them, and they all have to be changed every two years or so, on account of a deposit of calcium carbonate ("thornstone") which coats them. By whatever means the strong brine is obtained, it needs evaporation to produce white salt.

1207.



In England, as already stated, the brine comes up fit for use at once. In and around Winsford, are 35 salt-works, and 607 pans; in Northwich, 30 works, with about 485 pans; at Middlewich, 13 pans; at Sandbach, 68. At Droitwich are numerous works, mostly, however, on a smaller scale, with the exception of Chapel Bridge and Coverscroft. In Cheshire, the brine does not rise spontaneously to the surface in sufficient quantity to feed the works, but has to be extracted by pumping. It lies, as has been stated, on top of the rock-salts, on the corrugated surface of which it forms pools, or "runs," as they are often called. A shaft or well is sunk to the brine level, and the ingress of any fresh water from the overlying strata is guarded against by careful tubbing. The brine is then raised to the surface by means of pumps worked by steam power. The surface of the bed of salt is reached at a depth of about 40 yd., and the arrangements for the sinking and the pumping of the brine are so familiar as to need no description here. Suffice it to say that as brine exercises a solvent and corrosive effect on lead, and an oxidizing action upon iron, the use of either of these metals is to be avoided, either for the pipes or for the body of the pump itself; copper for the former and bronze for the latter are most to be recommended. Iron pipes are, however, usually employed in Cheshire and Worcestershire. Whole tree-trunks of elm or pine have been and are still occasionally employed, cut into short lengths, and joined together, and bored out as pipes, for conveying brine, and answer that purpose very well. In a few cases, the pump-shafts have been carried into old rock-salt mines, which have thus been utilized as solution-chambers, or reservoirs from which to pump brine. The strength of the brine obtained varies both with the locality and the season. The salt-makers say that the brine used in Cheshire contains about 2 lb. 10 oz. of salt per gal., but this is misleading. The writer is indebted to C. M. Blades, analytical chemist, of Northwich, for first drawing his attention to the following facts connected with this question. When salt was subject to a government duty, the excise officers were in the habit of estimating the strength of the brine by means of a "salinometer," a form of hydrometer graduated to indicate the amount of salt in lb. and oz. per gal., as shown at A, Fig. 1204. The old wine gallon then in use only contained 58,317 gr. of water, whereas the present imperial gallon weighs 70,000 gr.; but the salinometer used at that time is still retained by the manufacturers, while the new imperial gallon is the only one now recognized. The indications of this hydrometer are consequently misleading, and when, guided by this instrument, the manufacturer states that a brine of sp. gr. 1·204, and representing 26 per cent. of salt, contains 42 oz. or 2 lb. 10 oz. to the gal., his statement is erroneous. An imperial gallon of water weighing 70,000 gr. (10 lb.), an equal measure of brine of 26 per cent., and sp. gr. 1·204, should yield on evaporation 50 oz. (3 lb. 2 oz.) of dry salt, and this may perhaps be taken as an average strength for the brines of the Cheshire district. Misguiding as this may be, it has not so far led to any serious inconveniences, as the salt-makers usually purchase the brine from the owners of pumping-stations, paying on the amount of salt actually obtained. A change, however, in the mode of supplying brine is now taking place, and meters for registering the delivery are being introduced by several of the pumpers, with a view to check the enormous waste hitherto existing. In future, therefore, to avoid errors and simplify calculation, the present system of graduation of the salinometer will have to be altered. The French use the hydrometer of Baumé, or *pèse-sel*, which is constructed to indicate directly the percentage of salt in a given weight of brine, being graduated from 0 to 27. Twaddell's hydrometer indicates exactly oz. Av. of salt in the gal. of brine by the numbers engraved on its stem.

Otto Pohl found the average amount of salt in the Winsford brine to be 26·25–26·50 per cent. by weight, receding during rainy weather to 25. Thos. Ward states that the Cheshire brines usually contain about 25 per cent. (this is perhaps rather low for an average). As may be seen from the tables of solubility on p. 1711, the total solubility of pure sodium chloride in water at ordinary temperatures is about 27 per cent. The Cheshire brine may consequently be considered as a nearly but not quite saturated solution of common salt, especially when we remember that the small quantities of other salts present tend if anything to diminish the solubility of the sodium chloride. All natural brines employed in the manufacture of white or refined salt, whether derived from saline springs, from the concentration of sea-water, or by the direct solution of rock-salt, are contaminated with other saline constituents, of which the principal are magnesium chloride, and calcium sulphate; and it is a fact never to be lost sight of that all such brines, no matter what proportion of salt they may hold in solution, are as a rule saturated solutions of calcium sulphate. Were it not for the baneful presence of this calcium sulphate, and the pan incrustation chiefly due to it, the cost of producing white salt by artificial evaporation might probably be reduced by nearly one-third. Besides these salts, natural brines contain varying but small quantities of bromine, occasionally iodine, salts of potassium, and traces of iron, alumina, silica, boracic and phosphoric acids, &c. These other salts, however, interfere but little with the work of the salt-maker. In Cheshire, the brine is merely first pumped into reservoirs placed at such levels as to be able to feed the pans by an outflow-pipe. In these reservoirs, any insoluble suspended matter becomes deposited, and the brine then possesses a beautiful transparency, and a fine sea-green colour. In most of the Continental salt-works, the *bessoirs* already mentioned are employed. These require to be very carefully constructed, and are best arranged with external tie-rods armed with screws, so as to be able to tighten the joints from time to time.

In England, also, are wooden reservoirs for the brine in and about many of the salt-works, but they are usually fastened with tree-nails, and strengthened by stout timber ribs placed externally and very near each other, and the seams are kept tight by caulking; but they give endless trouble to keep them watertight. There is, however, probably far less loss under any circumstances from the wooden reservoirs than from those of puddled clay paved with stone generally used in Cheshire. The action of strong brine upon any wooden vessel in which it is stored, though highly preservative to the wood, is peculiarly astringent and contractile, and unless care be taken to provide against the emergency, it will be found that new wooden vessels, no matter how well made or how well the timber may have previously been seasoned, will not long stand the action of saturated brine, without requiring their joints to be tightened or caulked.

In cases where the brine is contaminated with any large quantities of magnesium salts, it is usual to decompose these in the *bessoirs* by an addition of milk of lime, the operation being called *chaulage*. The lime displaces the magnesium as a flocculent precipitate of hydrated magnesia, and decomposes at the same time any iron or aluminium salts, of which traces are usually present; it is added in just sufficient proportion for this purpose. As the precipitate accumulates in the *bessoirs*, they are cleaned out. The *chaulage* has been abandoned, except where necessity obliges it, for not only is the brine thereby made alkaline, and the crystallization rendered more difficult, but the liquor takes a long time to clarify, and during evaporation a crust is liable to form on the surface, which seriously interferes with the work. A far better plan is to wash away the magnesian salt, and other impurities that may be present, by a plentiful aspersion of the salt, after it has been made, with some saturated brine. In England, the brine as pumped and settled is sufficiently pure to be run at once in a continuous stream to the evaporating-pans, producing salt of superior quality, the mother-liquor hardly ever requiring to be run away till the pan is laid off for repairs (see Table opposite).

The nomenclature of the principal qualities of salt occurring in commerce may be stated as follows:—

Group I. Boiled.—Fine salt, sometimes called "lump" or "stoved lump"; superfine, also stoved; butter salt, not stoved; cheese salt, not stoved.

Group II. Not Boiled.—Common, fishery, extra fishery, double extra fishery, bay-salt.

In the French nomenclature, are *fin fin*, sometimes called *sel à la minute*, corresponding at the same time to our fine and butter salts; then 6-, 12-, 24-, 48-, 72-, and 96-hour salts, and another quality called *écailles*, a very coarse large grain, corresponding to bay-salt, chiefly made for sprinkling on the top of the salt fish in barrels.

The classification of the various qualities of salt varies with the size and appearance of its crystals, and these in their turn are almost entirely dependent on the rate at which the evaporation is carried on, and the greater or less degree in which the brine was agitated during that time. The boiled salts, produced during actual ebullition, and the liquid being frequently agitated, are fine in grain; the unboiled, produced by slower evaporation, are of coarser grain, according to the temperature, the time expended in their production, and the stillness of the brine during that process. The evaporating-pans are built of common boiler-plate, ¼–⅜ in. thick, the plates being about 4 ft. long by 2 ft. wide, and well riveted together. The plates are usually of rather smaller dimensions in the part immediately over the fire than elsewhere on the bottom or floor of the pan, as by this means some of the tendency to warp and buckle is supposed to be avoided. In England, the usual dimensions for fine and extra-fine salt-pans are 30 ft. long by 22–25 ft. wide, and 1 ft. 9 in. deep. This gives an evaporating surface of 720–750 sq. ft. Butter-salt pans are perhaps a trifle longer, say 35 ft. by 22–25 ft., and the same depth, with an evaporating surface of 770–875 sq. ft. Common and fishery pans range from 50 to 70 by 22–25 ft., and have the same depth, presenting an evaporating surface of 1100–1750 sq. ft.; some fishery salt-pans belonging to the British Salt Co. at Anderton are 90 ft. by 22, while at Stoke and Winsford, are fishery salt-pans ranging up to 130 ft. in length. Beyond 70 ft. in length, however, there really would not seem to be sufficient gain, at least with the quality of fuel used in Cheshire, to compensate the increased cost of construction and repairs. In France, the common and fishery salt-pans are about the same sizes as ours, only perhaps a trifle wider; and at Dombasle, near Nancy, where the intelligent manager Botta has carried the manufacture to as great perfection as is attained in perhaps any works, the pans (*poêles*) are 72 ft. by 29½ ft. by 43½ in., with an evaporating surface of 2124 sq. ft.

TABLE IV. ANALYSES OF BRINES.

AUTHORITY.	A. B. Northcote.				Heine.		Fehling.				Maxwell Lyte.
	Cheshire.		Worcestershire.		Schönebeck.						
LOCALITY.	Marston.	Wenlock.	Droitwich.	Stoke Prior.	Before Graduation.	After Graduation.	Clemenhall.	Sulz.	Friedrichshall, Wurtemburg.	New York, Salina from the Carboniferous Formations.	Dax, in the South of France.
CONSTITUENTS.											
Sodium chloride ..	25·222	25·333	22·452	25·492	10·404	25·160	25·902	23·473	25·563	13·239	25·273
Magnesium ,, ..	..	0·171	..	..	0·073	0·630	Traces	..	0·006	0·046	0·030
Calcium ,, ..	..	..	..	..	..	..	..	..	..	0·083	0·105
Sodium bromide ..	0·011	0·020	Traces	Traces	..	..	..	..	..	..	0·016
Sodium iodide ..	..	..	..	..	..	..	..	..	..	..	..
Sodium sulphate..	0·146	..	0·390	0·594	..	..	0·019	..	..	..	..
Potassium ,, ..	Traces	Traces	Traces	Traces	0·148	0·550	..	..	..	..	..
Magnesium ,, ..	..	..	..	..	..	0·130	0·610	..	0·002	..	..
Calcium ,, ..	0·391	0·418	0·387	0·261	0·281	0·170	0·444	0·508	0·437	0·569	0·357
Sodium carbonate	0·036	..	0·115	0·016	..	..	..	..	..	..	..
Calcium ,, ..	..	0·052	..	..	0·049	..	0·019	0·016	0·010	0·014	0·015
Ferric oxide and alumina ..	..	..	..	..	..	..	..	..	..	0·002	0·012
Silica	..	..	..	..	..	..	..	..	..	..	0·005
Water	..	..	..	..	..	..	73·615	..	73·982	..	..

In this table, the presence of calcium chloride in the Dax brine, of the sodium sulphate in the Worcestershire brine, and the large proportion of potassium sulphate in the Schönebeck brine, are specially to be noticed. It is stated by the salt-makers of Cheshire that the Worcestershire brine works far more easily than theirs. If such be the case, it may be attributable to this peculiarity of composition.

The floor of a pan is usually made slightly arched upwards towards the centre, so that a new pan is rather deeper at its sides than in the middle; but they soon flatten out and warp in various directions under the influence of the firing. On the Continent, cast-iron pans have been in some cases adopted, and cast-iron plates substituted for the smaller wrought-iron ones universally employed in this country in the part of the pan just over the fires. Besides the advantage accruing from the less tendency to buckle and warp, the cast-iron has a much higher conductive power than the wrought-iron, and the advantage of cheapness. The plates are not made much thicker than the ordinary wrought plates, and are cast with exterior flanges all round their edges, by which they can be bolted together beneath the pan. They also have grooves cast in their edges, to receive asbestos cord or cement, by which, when screwed up, they can be made watertight. Were it not for fear of their greater fragility and some difficulties of adjustment, they would doubtless be employed in this country, thus avoiding leakages into the flues, and the consequent production of large stalactites of salt, technically termed "cats," an intolerable nuisance to the salt-maker. In Austria, such cast-iron pans are actually now in use, and their advantages will be manifest from the following comparative experiments made at Berchtesgaden under like conditions of firing, &c.:—

	Temperature attained in the pan.	Cost of maintenance. £	Durability.
Sheet-iron	64·4° F.	74·8	12 years.
Cast-iron	75·2° F.	34·4	21 years.

It is also sometimes the practice abroad to make the pans with plates riveted on to ┬-iron bars running across the width of the entire pan, the central flange of the ┬-iron standing up between the edges of the plates, and these latter having the rivets countersunk into them. This seems somewhat to prevent the buckling.

1208.

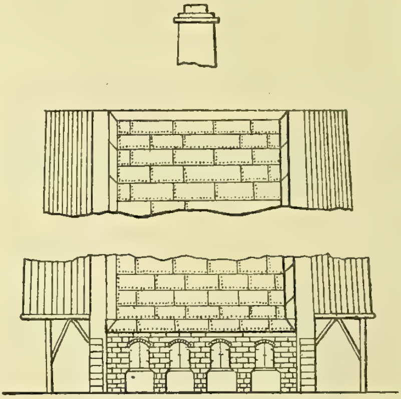
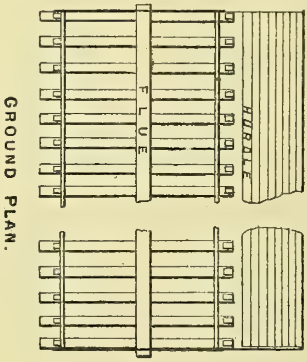


Fig. 1208 represents the usual mode of setting pans in Cheshire, the two ends only being given, showing the positions of the chimney and the fires. This may be taken as illustrating any of the ordinary pans, whether for boiled or unboiled salts, the sole difference consisting in the respective lengths of the pans.

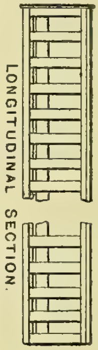
Wooden pans even have been and still are employed. One belonging to Thompson, of Northwich, is 4 ft. 6 in. deep, 12 ft. wide, and 75 ft. long. The two ends are of sheet-iron, and a long sheet-iron cylinder, closed at the two ends by steam-tight doors, runs from end to end. This cylinder is about 18 in. diam., and is supplied from above at about the middle of the pan by means of a lateral pipe with waste steam from an engine and boiler near. By this, the pan is kept at a temperature of about 90°–100° F. This pan is said to produce 45–50 tons of extra fishery salt every 6 weeks or so. Figs. 1209–11 represent such a pan, of which there are several at Northwich, in plan and in longitudinal and transverse sections, as well as the house containing it.

In Cheshire and Worcestershire, the fire-places, usually 4 in number, measure about 4–5 ft. from the door to the back, and are about 3½–4 ft. wide; from the bottom of the pan to the grate-bars is usually about 3 ft. In the case of very long pans, this height may increase to 3 ft. 4–5 in. The grates are formed of square wrought-iron bars, it being found inconvenient in salt-works to employ the improved cast-iron "fishbellied" bars. This is on account of the great liability to choking with clinkers, and caking of the ashes with the brine which drips from leaks over the fires fusing into clinker, and clogging the grate-bars. The blows necessary to detach these masses would seriously endanger cast-iron bars; but certainly the shape of the bars might well be improved, and rocking-bars, such as those employed in pyrites-kilns and elsewhere, might be more generally introduced with advantage. The firing is usually done in a stoke-hole with steps on each side leading up to the pathway around the pan.

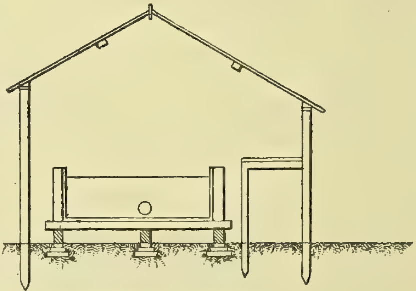
1209.



1210.



In France, often 2 fires only are put under each pan. The general construction of a French salt-works is rather more regular than in those of this country, and the pans are usually placed side by side in sheds, while a common flue connects with the outlet-flue of each pan, and such arrangements are made that, when required, any one pan can be cut off by a damper. This common flue is made to pass beneath one or more long deep pans fed with cold brine, and from these the brine is fed, already more or less warmed, into the evaporating-pans. English pans are always set on brick-work, and their bottoms stand about on a level with the ground, overlapping their sustaining walls by some inches, and reposing on longitudinal flues. These latter are usually 4, corresponding in number with the fires, and run straight nearly the whole length of the pan, sometimes entering a chamber at the far end, and passing thence to a low chimney serving one or two pans; but sometimes they converge simply into one common flue, running the whole length of a row of



1211.

pans, and having an exit to the main chimney. At times the flues do not continue the whole length of the pan, which is then supported here and there by pillars or bits of wall built in parallel lines. Sometimes no flues at all are employed, the pan being merely sustained by pillars of brickwork, sandstone, or cast-iron. The whole space then beneath the pan constitutes one large flat flue, through which the heated gases find their way unencumbered. This plan is common in Worcestershire.

On the Continent, other dispositions of flues are often adopted. At Nancy, and pretty well throughout France, the flues from each fire (often only two) run down to the end of the pan, returning towards the fire-end, and back again once more to the chimney or main flue, each flue thus forming 3 parallel lines. This plan has been tried in England, but is not now usually employed, the simpler form of straight flues leading from each fire right away to the chimney or common flue seeming generally to be preferred. Here in England also they usually have two "dead" flues, as they call them, one on each side beneath the pan, these being spaces like flues, but completely walled up at each end, so that no gases can enter them, as shown in Fig. 1225, p. 1739. This represents the arrangement of flues now generally adopted. The flues are usually 2–3 ft. deep, of a capacity in fact to admit a man or boy; and between the entrance of the flues and the fire-place, is built a wall of fire-brick, reaching to within 18 in. of the bottom of the pan. Over this "bridge," as it is called, the heated gases pass before entering the flue, and as the bricks of the bridge become red-hot, they tend to induce a more perfect combustion of the smoke before it enters the flues, where it would become too rapidly cooled by contact with the bottom of the pan, and soot would fall.

In Cheshire, and other places in England, the evaporating-pans are at times employed quite open and exposed to the sky, but nowadays they are mostly surrounded with sheds, these being furnished with ventilating openings in the roof, to facilitate the escape of steam. On the Continent, all except the fine and butter-salt pans are generally covered in with wooden trunks, flat on top with sides converging upwards, thus forming an elongated truncated cone about 5 ft. high over the pan. All along the lower parts of the sloping sides of this cover, and on both flanks of it, are frames fitted with shutters removable by hand. By removing one or other of these, the progress of the crystallization may be watched. A shelf is sometimes made, running along the whole length of this cover of the pan, just above the shutters; and when the pan is drawn, the workmen fish out the salt with rakes and scoops, and let it drain a bit on the drainers alongside of the pan, corresponding to what our salt-makers call "hurdles," and then pitch it overhead on to this shelf, on which it is allowed to drain pretty completely, the drippings falling back into the pan; thence it is shovelled on to the flat top of the cover of the pan, which is set with tiles. On these tiles, which are kept hot by the steam within the trunk during the time the pan is at work, the salt becomes dried, and is then on a level with the bins (*magasins*) into which it is tipped from waggons for storage. From that end of the trunk furthest removed from the fires, rises a wooden chimney 10–15 ft. high, for carrying off the steam from each pan; it passes through the roof of the building in which the work is carried on. Sometimes fan-blowers are placed in this and the main chimney, to expedite the exit of the steam. It is asserted by many of the French salt-makers that notwithstanding the greater cost of covering in the pans in this manner, the lessened facility of egress for the steam, the inconvenience, and the somewhat larger amount of labour involved in drawing the pans, they are compensated by a considerable economy in the combustible employed, through the diminished loss of heat by radiation; certainly they obtain cleaner products than English salt-makers. At the Dombasle salt-works, one of the best-managed and best-organized in France, the writer has, on the contrary, noted that with 100 *kilo.* of the small, poor coal from Saarbrück they only produce 160–170 *kilo.* of common salt. This coal is, however, far inferior to the slack used in Cheshire and Worcestershire, and it is not employed for fine or butter-salt, being unable to maintain a pan in continued ebullition, so small is its heating power. It is used on account of its low price, and its yielding a gentle diffused heat suitable for the work.

The stoves in which "lumps" of fine salt are dried in England are low rooms usually placed at the ends of the butter and fine salt-pans. Through these pass the flues conveying the still heated gases to the chimney. The gases from the boiling pans are employed by preference, as they emerge at a higher temperature than from the non-boiling pans, and the flues conveying them become very strongly heated. Sometimes these flues are carried below the ground, sometimes above, the intervals between them being then termed "ditches." In either case, the flues are covered with cast-iron plates, and are made to wind about in the stove-room, so as to present a considerable radiating surface. The temperature of these rooms is usually 49°–65½° (120–150° F.), often even higher. The floor of the room and the iron plates covering the flues are bestrewn with common white or ground rock-salt, to an inch or two in depth, and this forms a warm, dry, and absorbent bed of material on which the lumps of salt rapidly become dried. Their dryness is recognizable by their peculiar ring on being struck, as compared with the duller sound they emit while at all moist.

Manufacture of Boiled Salts.—For fine, superfine, butter-, and cheese-salts, the pan employed is not more than 30–35 ft. long, sometimes as low as 25–26 ft., by 22–25 ft. wide. The salt is fished out of these pans twice each day, perhaps a little oftener for butter-salt, and the pans have to be laid off and scaled every month, or even oftener. These boiled salts are all fine-grained, some rather finer than others. This fineness is obtained by keeping the brine not only boiling, but well agitated by raking. Superfine salt is but the same rather more carefully made, and subsequently ground. Butter- and cheese-salts, which hardly differ from each other, are not stoved. The salt from the boiled-salt pans is drawn to the sides of the pan by iron rakes, when it is lifted out of the brine by means of perforated shovels, called "scoops," the ends of which are turned up for this purpose, as shown at C, Fig. 1204. Two forms of drainers are used in Cheshire, one conical, called a round tub or basket, the other, already mentioned, called a square tub. The former vary rather in capacity, but usually they are about 3 ft. from the brim to the end of the foot. Square tubs are 18 in. long by 7 in. sq. at one end and 9 in. sq. at the other end, consequently they form truncated quadrilateral cones. Their bottoms are removable. For the purpose of filling, the round tubs are ranged, standing on their pointed ends in the brine, around the inner sides of the pan, and as the salt is fished up, they are filled with it one after the other. The square tubs are filled in the same manner, only where these are used, the pan is surrounded with a sort of gallery or platform of bar-iron, on the inside, just barely below the surface of the brine, on which the tubs are placed to be filled. They are then carried to the stove-room, where they are inverted, and the shapes of salt are turned out and left to dry. When the lumps made in the square tubs are dry, about 80–84 of them go to the ton.

When a pan of any of the boiled salts is to be started, the brine is run in, and some gelatine, glue, or sometimes blood, is added, while the fires are urged till the brine boils. A scum rises to the surface as the heating proceeds; this is removed, and the brine, from having appeared at the first heating rather opalescent, becomes clearer, while the bottom of the pan gets whitened with an incrustation, particularly at first just over the fires. At the same time, if the brine is strong and good, there tends to form all over its surface a crystalline pellicle or crust. If fine salt is being made, this is broken down by striking the water with a flat piece of wood from time to time; but when the boiling commences, this pellicle breaks up as fast as it forms, and the floating bits of salt drift from the fire end of the pan towards the other, where they sink and accumulate. This operation goes on continuously, and the salt by this means falls down during the whole boiling in largest quantity at the end of the pan farthest from the fires, and when enough salt has accumulated to make it worth while, the pan is drawn. This is under ordinary circumstances about twice a day; for butter-salt, perhaps a little less often. A pan of 33 ft. by 24 ft., which may be recommended as a convenient size for boiling, ought to yield 5–6 tons of salt per 24 hours, making 30–35 tons a week. But including stoppages for scaling and repairs, and taking into account the diminished yield when the pan gets very thickly encrusted, the real yield can hardly be reckoned at over 25 tons a week. The process is continuous, brine being run in as fast as the evaporation proceeds, the pan being thus always maintained about three-quarters full. The scale which forms on these pans is usually very thick, and contains a very large proportion of mechanically combined salt. This kind of scale is called "salt-scale," in contradistinction to that which forms on the unboiled pan, called "pan-scale" or "sand-scale," and which differs essentially from it in composition. Analyses of samples taken from the works of Thos. Ward and Messrs. Gibson will be found in Table V., p. 1733. Several inches of this scale will sometimes form in the course of a week in these boiled-salt pans, and, as may well be supposed, most seriously diminishes the evaporative duty of the coal. The fine and butter-salt pans are usually scaled once a week, and require very frequent repairing. For this purpose, the fires are extinguished, and the pans emptied of their brine, which is usually run to waste, when workmen enter, break up and chip off the scale with picks, and shovel it away. Attempts have been made to do this scaling without emptying the pan, and at the Stoke works near Droitwich, this work is performed every two days by a man wading about with his feet in two wooden buckets. This is a decided advance on the method usually employed. The boiled-salt pans are liable to a sort of efflorescence of salt over their edges, which is cut off from time to time, and which, if not removed, would often siphon the brine to a considerable extent out of the pan by capillarity. These cuttings are sold for use in agriculture under the name of "claggings," and the salt-scale is at times ground and sold for the same purpose. The latter has also been employed in making coarse glass, and some is at present sold for fluxing purposes in metallurgical operations. It will be necessary to return to these boiled salts when considering machine and composite pans, and the Otto Pohl process.

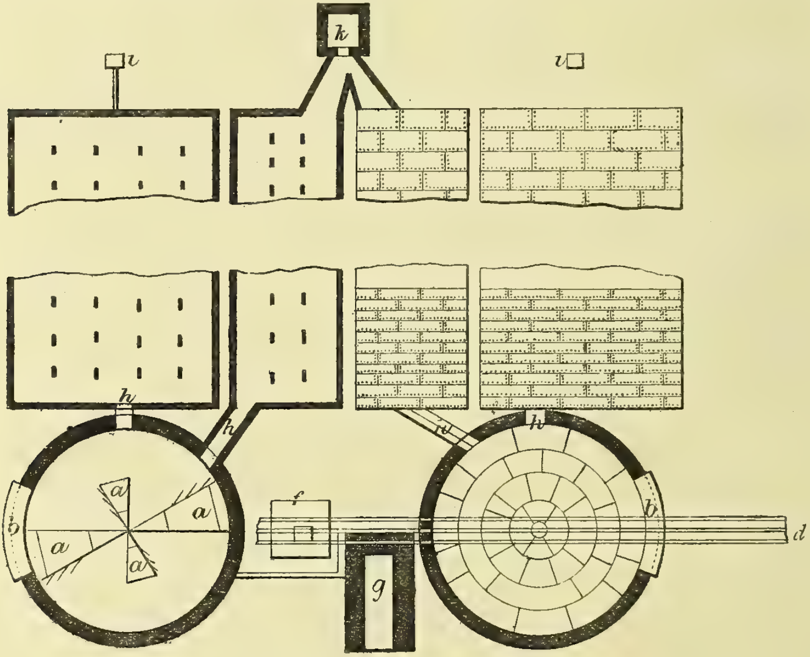
Manufacture of Unboiled Salts.—The various qualities, which only differ from one another in the size of the grain and their more or less perfect crystallization, depend for their production on the slow evaporation of the brine at temperatures far removed from boiling. They include the so-called "common" salt, the different qualities of "fishery-salt," and that known as "bay-salt." Whereas the length of the pans in which the boiled salts are made is limited to 35 ft. at the outside, it being impossible to keep longer pans in a constant state of ebullition without such fierce firing as would destroy them; on the other hand, in the manufacture of the coarser-grained unboiled salts, the length of the pans is increased till all chance of boiling is avoided, while a greater economy of fuel is attained. When a pan of cold brine begins to be fired, that part of the brine immediately over the fires naturally first takes the heat, and, growing lighter by expansion, rises to the surface, the colder brine from the further part of the pan running in from below to take its place; the warm brine, then gradually diffusing itself on the surface, goes to the far end of the pan, where, cooling by evaporation or by contact with the other cold brine, it sinks, returning to the hot end of the pan to become once more heated. Thus is established a circulatory movement in the brine, a supernatant current of warm liquid flowing from the fire-end, and a cooler current always flowing back below; this continues so long as the brine is kept only gently heated and is not actually boiled. As soon as any excess of water the brine may have contained has become dissipated, the salt begins to form, producing the "hopper-crystals" already mentioned; while a crystalline crust collects on the surface, and drifts towards the further end of the pan, there sinking to the bottom. To avoid too much salt thus drifting to the far end of the pan and filling that part too rapidly, thin narrow laths of wood are stretched across the surface of the brine, which stop these floating crystals and cause them to fall down. When a pan is first set down, it is customary to add 2–12 lb. of alum for a pan three-quarters full of brine. Alum is particularly used in this way in making fishery-salt. The brine is first made to boil, or very nearly so; the fires are then damped down a little, and the temperature is thus maintained and the evaporation allowed to proceed at a lower point, according to the quality of salt required. About 180° F. (224° F. being the temperature at which saturated brine boils) is the temperature for common salt. On the first heating, a scum rises to the surface, as in the case of the boiled salts. This scum is mostly due to the alum, which is decomposed, and the alumina comes to the surface, carrying with it any suspended insoluble matters, and perhaps taking up organic impurities the brine may contain. As previously stated, most brines (those of Cheshire form no exception) are saturated solutions of calcium sulphate, as well as of sodium chloride; and calcium sulphate is one of the few salts known to be *less* soluble in hot than in cold water. The consequence is that the brine, besides containing some trifling particles of suspended matter, becomes more or less clouded by a deposit of calcium sulphate, possibly also by a little calcium carbonate when first strongly heated. This either falls down as incrustation, or rises to the surface in the scum, and thus the liquor, which had become a trifle turbid, again clears. Alum is also occasionally, but not so often, used in this way for butter-salt, and at times, in the case of boiled salts, a small lump of butter or grease is added; this has a tendency to break up and throw down the crystals. These are among the supposed secrets of the salt-makers, and the substances thus added are termed by them "poisons." The scale from unboiled pans differs considerably in composition from that formed in the boiled pans, as shown by the annexed table :—

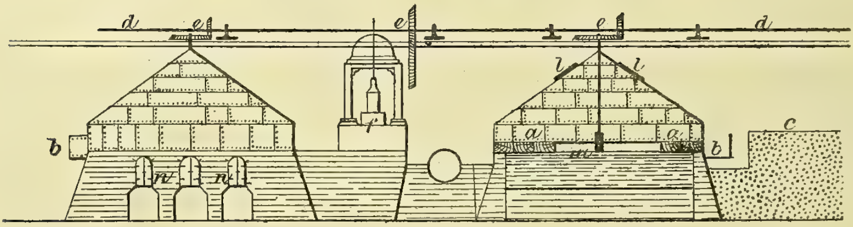
TABLE V. ANALYSES OF PAN-SCALES.

LOCALITY.	Turrenburg.	Anderton, near Northwich.	Dax, South of France.	Verdin's Works at Winsford.		
	From Unboiled Pans.				Boiled Pans.	
AUTHORITY.	Heine.	Tookey.	Maxwell-Lyte.	Maxwell-Lyte.	Tookey.	Maxwell-Lyte.
COMPOSITION.						
Sodium chloride	10·77	0·14	0·19	0·07	90·62	87·02
Sodium sulphate	9·05	..	4·30	..	..	..
Potassium „	1·02	..	traces	traces	..	..
Magnesium „	0·43	..	..	..	..	..
Calcium „	71·94	83·00	82·26	87·00	8·02	9·86
Magnesium carbonate ..	0·21	..	0·30	0·10	traces	0·05
Calcium „ ..	0·09	1·07	2·79	0·27	0·25	0·30
Ferric oxide and alumina	0·13	traces	1·53	0·52	traces	0·30
Silica	0·15	..	0·28	0·37	..	..
Water	6·19	15·65	5·21	11·67	0·90	1·97
Totals	99·98	99·96	99·86	100·01	99·79	99·50

To fill a pan with salt, the brine being allowed to flow in a small gentle stream in quantity sufficient to replace that lost by evaporation, takes, in the case of common salt, working at a temperature of 71°–82° (160°–180° F.), 48 hours ; common or Scotch fishery salt, working at 54°–71° (130°–160° F.), 4–5 days ; extra fishery, working at 38°–43° (100°–110° F.) and in long pans, 7–8 days; double-extra fishery, working at about 32° (90° F.), 10–14 days; large-grained bay-salt, working at 24°–27° (75°–80° F.), 3–4 weeks. The "wych-house," as the wooden shed is called in which the evaporation is carried on, is 15–18 ft. wider than the pan itself; on each side of it, abutting against its walls, are low shelves of boards, placed near the ground, sloping gently inwards, and running the entire length of the pan, though separated from it by a pathway in which the workmen can circulate. On to this shelf the salt is thrown to drain, one workman drawing it to the side of the pan with a rake, while another fishes it out with a scoop or skimmer. The men who work at the drawing of the pans are called in Cheshire "wallers," and the boards on to which it is thrown are called "hurdles." These latter (Figs. 1208–9) are 5–6 ft. wide. The salt is taken from them in wheelbarrows or trucks to the store by men termed "lofters." In England, it is generally managed, if possible, to place the wych-houses on a higher level than the store, so that the salt when wheeled there may be tipped from above into the bins reserved for each kind; but in France, the construction of a salt-works to meet the requirements of the excise will rarely permit of this, so the pans and the bins into which the salt is tipped are put on about the same level, the salt being lifted from the hurdles to the tops of the covers (*hottes*) of the pans, on which it is dried before storage, instead of being merely drained on the hurdles as in England. This mode of treatment depends on the heavy tax (125 *fr.* or 5*l.* a ton) levied on all salt for domestic purposes in France, chemical and agricultural salts being alone exempted. Two excisemen are attached to and obliged to live in every French salt-works, while the works are compulsorily surrounded completely by a

1212.





1213. 1214.

wooden palisade about 7 ft. high and reaching the ground, the laths of which must not be over ⅜ in. apart. There must be likewise but one gateway to the works. The result of drying the salt before placing it in the bins is that these French salts nearly always gain rather than lose weight in transport, attracting more or less moisture from the atmosphere; and being always in sacks, the purchaser feels that even if he has to pay a heavy tax, he gets good weight for his money, while the salt-maker pays his tax on the lowest weight possible. The tax in France has likewise tended generally to make the manufacturers (*saulniers*) careful to produce the finest and purest article practicable. They have likewise protected themselves by syndicates in the respective districts, so as to ensure against over-production, and they have thus succeeded in maintaining prices at remunerative rates. Further, as the tax is often only made payable 4–5 months after the salt has left the works, though sales are effected at short dates of payment, large sums constantly lie in the hands of the manufacturers, and more than suffice to form their floating capital.

The quantities of coal used in the manufacture of salt vary according to the kinds of salt, and also somewhat in the different works. The boiled salts take the most coal, as the gases leave the pans at high temperatures. Common salt is about the most economical of fuel, the different fishery-salts and bay-salt occupying positions intermediate in this respect between the two. Fine salt takes about 13 cwt. per ton of salt; part of this heating power goes to maintain the temperature of the stoving-room. Common salt should take but 9 cwt. of coal per ton of salt. The fuel used in the Cheshire salt-works is the small coal called "slack" from Lancashire and Staffordshire; and "burgey," i. e. small and large mixed just as they come from the mine, mixed with the slack or by itself, is often used for boiled salts. Small coal is preferable for producing the mild heat required in salt-making, and has the further advantage of cheapness.

The annexed tables, giving the analyses of some British and foreign white salts, will be of interest:—

TABLE VI. ANALYSES OF COMMERCIAL WHITE SALTS.

AUTHORITIES.	Henry.	Ure.	Watts.		Richardson and Watts.	Fehling.		Maxwell Lyte.	Crace Calvert.	Maxwell Lyte.	Virch.		Heine.
LOCALITY.	Cheshire, Fishery dried at 212° F.	Cheshire, Stoved.	Schönebeck.	Stassfurt.	Spencer, New York.	Wilhelms-Gluck.	Friedrichshall, Butter Salt.	Dax, Common Salt.	Cheshire, Agricultural Salt.	Machine Pan Butter Salt from Winsford.	Seelz, in Mecklenburg, Butter Salt.	Ditto, ditto, Common Salt.	Artern.
CONSTITUENTS.													
Sodium chloride ..	98·60	98·250	95·402	97·094	96·29	98·900	97·550	98·500	95·82	95·272	93·79	90·75	96·53
Potassium " ..	..	..	..	..	Trace	..	..	..	..	..	0·89	1·00	..
Calcium " ..	..	0·025	..	0·345	Trace	..	..	0·010	Trace	..	0·26	0·99	..
Magnesium " ..	1·10	0·075	0·800	..	0·27	..	..	0·037	..	0·014	0·14	0·60	..
Sodium sulphate..	..	..	..	..	Trace	0·005	..	..	..	..	..	..	0·96
Potassium " ..	..	..	0·414	0·390	..	..	..	..	..	..	..	..	..
Calcium " ..	1·20	1·550	0·732	0·727	1·39	0·498	0·934	0·452	..	1·900	1·44	0·59	0·64
Magnesium " ..	..	..	0·471	0·180	..	..	0·009	..	..	..	..	..	..
Ferric oxide and alumina ..	..	..	..	..	0·25	..	..	0·090	..	0·160	..	..	..
Insoluble matter..	0·10	..	..	..	0·03	..	..	..	..	0·041	..	..	..
Calcium carbonate	..	..	..	..	..	0·005	0·016	..	..	..	..	..	..
Water	..	..	2·901	1·264	2·20	0·602	1·488	1·890	4·18	2·605	3·88	6·48	1·86
Total ..	101·00	99·890	99·920	100·001	99·23	100·010	99·997	99·889	100·00	99·992	..	..	..

TABLE VII. ANALYSES OF AMERICAN AND ENGLISH SALTS—(Porter and Goessman).

	AMERICAN.									ENGLISH.			
LOCALITY.	Onondaga.	Hocking Valley.	Mason City.	Onondaga.	Turk's Island.	Onondaga.		Ashton.		Stubbs.	Ashton, Northwich.	Deakin.	Marshall.
	Fine Boiled Salts.			Coarse Salts.		Dairy Salt.							
CONSTITUENTS.													
Sodium chloride ..	97·12	93·26	95·77	97·31	96·76	97·760	97·672	97·59	97·660	98·0229	97·7598	97·4728	98·4065
Calcium " ..	0·15	1·43	0·61	0·05	..	..	..	0·01	..	..	..	..	..
Magnesium " ..	0·13	0·70	0·04	0·05	0·14	..	..	0·03	0·059	0·0124	0·0591	0·0353	..
Sodium sulphate ..	..	..	..	..	0·64	0·025	0·008	..	..	..	..	..	0·1135
Calcium " ..	1·33	..	..	1·05	1·56	1·295	1·235	1·67	1·381	1·3798	1·2272	1·4413	0·8888
Magnesium "	..	..	..	..	..	0·066	0·082	..	..	0·0817	0·0769	..	0·0281
Insoluble matter ..	..	0·01	0·11	..	..	0·130	0·124	..	..	0·0616	0·0564	0·0490	0·0500
Water	1·27	4·60	3·47	1·54	0·90	0·724	0·879	0·70	0·900	0·5620	0·7880	0·9520	0·4940
Total	100·00	100·00	100·00	100·00	100·00	100·000	100·000	100·00	100·000	100·1204	99·9674	100·0757	99·9809

With regard to Tables VI. and VII., it is to be noted that samples taken fresh from the bins generally contain more water than shown in the analyses, unless the salt has been dried before storage. The water usually amounts to 3–4 per cent. for butter-salt, 5–6 for common salt, and 7–8 for fishery-salts, while some extra fishery-salts contain even more. This water, however, being for the most part merely mechanically held between the crystals, drains away during transit or long storage.

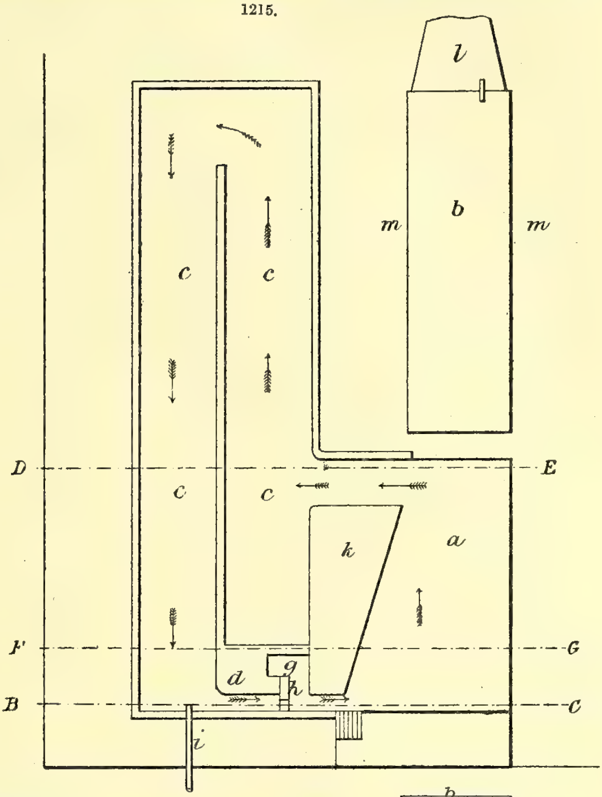
The innovations introduced of late years in the salt manufacture require to be shortly alluded to. Both in England and abroad, attempts have been made to reduce the loss of heat, chiefly due to the scale in the pans and the soot of the flues, by heating by steam. Whatever economy there may be in this method, it has not made much progress among English salt-makers, though the system is a common one for other purposes in the salt districts. The steam-pipes get covered with scale, which is difficult to detach without injury to them, and they are rather in the way of drawing the pans.

So-called "machine-pans" are employed at the works of Verdin, Falk, and the British Salt Co., and probably elsewhere. These are round pans, Figs. 1212–4. They are usually worked in pairs, standing 20–30 ft. apart, with a small engine *f* between, or a shafting *d* running above several of them driven by an engine at one end; this shafting is geared by bevel-wheels *e* to the stirrers *a*, and is so arranged that any one or more of the pans can be thrown into or out of gear at will. The depth of the pans is 2 ft., and an opening is left in one side of each down to the bottom, this opening being closed with outside troughs *b* riveted to the sides of the pans. The bottoms of these troughs go lower than the bottoms of the pans, so that any salt swept out of the openings falls into the troughs, and cannot return into the pans. The pans are fitted with conical covers of sheet-iron, through the centre of which pass iron spindles, geared above to the pinions of the shafting by bevel-wheels, and resting on the bottoms of the pans, in which they are free to turn. These spindles are attached at their lower parts to the arms or stirrers *a* carrying scrapers swinging loosely beneath them, and resting on the bottoms of the pans. The covers are fitted steam-tight upon the tops of the pans, and each is provided with one or more manholes *l*, by which workmen can enter to clean the pans. Those parts of each cover corresponding to the parts left open in the sides of the pans are brought down so as to partially close the openings and come just low enough to dip into the brine about 2 in., when the pans are about ⅔ filled, while the spindles passing through the covers turn in stuffing-boxes. Thus, when the pans are closed, they are steam-tight, and there is no exit for the steam unless by forcing the water out of the pans into the troughs *b*, or passing off by the flues *h*. Each pan is fired by 3 fires, and boiled as for fine salt, while the spindle carrying the arms and scrapers is made to rotate. The incrustation of the pans is thus for the most part avoided, while very fine salt is produced, and is swept by centrifugal motion into the troughs, whence it is continuously ladled with a scoop, drained on "hurdles" *c*, and sent to the stove or the butter-salt bins, as the case may require. The steam-pipes discharge beneath the two fishery-salt pans, occupying the central position in the figures, while the gases from the fires under the pans, and perhaps from the fire of the engine, are made to pass to the flues beneath the outer pans. Both the pans which are heated by the steam stand on short brick or iron columns without flues; the pans taking the waste gases are set upon winding flues such as already described as being in frequent use in France.

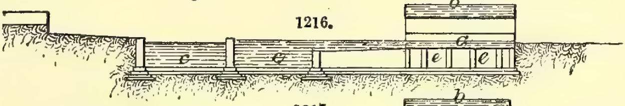
At the works of the British Salt Co., at Anderton, a 3–4-H.P. engine stirs three pans, and it is stated that, with a consumption of 40 tons of coal, a pair of these pans, with their concomitant fishery-salt pans, will turn out 60 tons of fine salt and 24 tons of fishery-salt per week. The fine salt produced in these machine-pans is very fine and fairly white, but usually contains just a trace of iron, which communicates to it the faintest possible shade of yellow.

Sometimes an ordinary boiling-pan is mounted with a fishery-salt pan behind it, so that the flues from the former passing beneath the latter, this pan also becomes heated by the waste gases. The Cheshire Amalgamated Salt Co., one of the largest and most important of the district, have in their works at Winsford some rather interesting and peculiar composite pans, known as "clay" or "tank" pans, also working on this principle. Fig. 1215 represents a ground plan of this arrangement, and Figs. 1216, 1217, 1218, are transverse sections on the lines D E, F G, B C, respectively. The boiling-pan *a* is placed with its upper edge on a level with the ground or barely above it. It is of the usual depth of 1 ft. 9 in., and of the form shown. The fishery-salt pan *b* utilizes the waste heat of the furnace-gases, after they leave the flues beneath *a*. There are 3 fire-places *f*, and 3 flues *e*, beneath *a*, together with 2 dead flues. Alongside of and parallel with the pans *a b*, is a pit or trench *c*, about 4 ft. deep, 10–12 ft. wide, and 38–40 ft. long. It is puddled with clay and lined with bricks throughout the sides and bottom. The upper edges of this trench are about 4–5 in. below the level of the upper edge of the pan *a*. A parting wall of brickwork also divides this trench *c* longitudinally into 2 compartments of equal width. This wall, however, only goes to within about 10 ft. of the end of the trench furthest from the fires, and to within 2 ft. of that end which is in a line with them. The side of the pan *a* turned towards the trench is cut out at the end furthest from the fires, and a shallow channel of sheet-iron, just as deep as the pan, connects it with the double trench, while the space *k* contained between *a* and the trench is filled up with a bed of masonry, the surface of which slopes gently from the upper edge of *a* towards *c*, so that the waste brine from any salt drawn on to it may drain into *c*. *k* is connected with *d*, as shown in Figs. 1215 and 1217, by a short wall, and a pump is placed at *h*, while another sheet-iron channel, only 2 ft. wide, but of the same depth as *a*, leads between the pump and the pan *a*. There is a small pit *g*, made of masonry, at the end of this channel; and at the end of the parting wall, at *d*, is a flat space just large enough for a man to stand upon to look after the pump when requisite. With this arrangement, if brine be poured in by the brine-pipe *i*, *c* will be filled, and if the influx of the brine be continued, *a* and *b* may be filled till *c* is nearly overflowing, and *a* becomes full to within 4–5 in. of its upper edge. If then the pump *h* be worked so as to lift the brine from *c* and cause it to fall into *g*, it will flow back into *a*, and, circulating through *a*, will pass again into *c*; thus a steady circulation of the brine may be maintained in the directions shown by the arrows on the ground plan, so long as the pump is kept going. If then the fires *f*, Fig. 1218, be lit, the brine will be heated in *a*, and, circulating in the manner described, expose a large evaporating surface. The heat is so managed in these pans as to produce butter-salt in *a* and common salt in *c*; while at *g*, where the pump produces constant agitation, very fine salt is formed. Around the clay pan, the butter-salt pan, and the fishery-salt pan, are the usual paths for the circulation of the workmen, and the places for the so-called "hurdles" *m* upon which the salt is thrown to drain. The stoke-hole is below the level of the ground. The fishery-salt pan *b* may be mounted on columns of brickwork or cast-iron without separate flues, and a chimney at the end of this pan carries off the furnace-gases. These pans seem to produce very fine qualities of salt, particularly the common salt from the pit *c*. The yield is about the same (as regards weight of salt to weight of coal consumed) as with the ordinary pans, but the repairs are somewhat less, and certainly the qualities of salt produced are very fine. The chief drawback to them is a rather greater tendency of the pan *a* to become coated with scale, than in the case of the ordinary butter-salt pans.

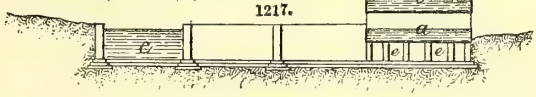
1215.

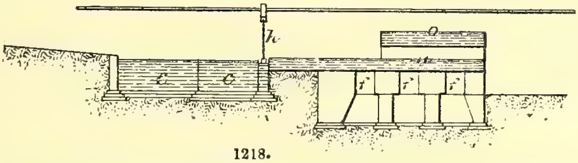


1216.



1217.

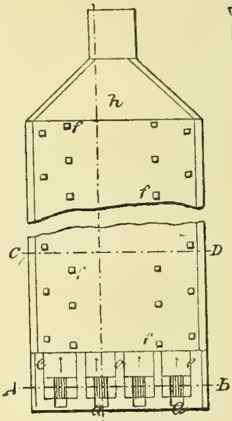




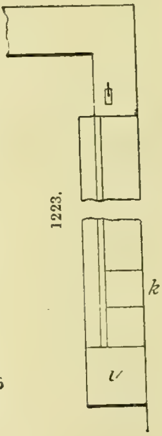
1218.

The last innovation in the salt manufacture here to be described is that of Otto Pohl, salt manufacturer and merchant, of Liverpool. This invention has, perhaps, not met with all the attention it deserves on the part of the salt manufacturers. The arrangement consists of two superimposed pans, at one end of which the fires are placed; the heated gases, passing between them to the chimney at the other end, heat the upper pan from below in the ordinary way, while they sweep the surface of the brine in the lower pan, which thus constitutes the bed of this portion of the flue. Figs. 1219, 1220, 1221, 1222, 1223, and 1224 show this arrangement in ground plan, longitudinal and transverse sections, and in side and end elevations. Milner, of Marston, near Northwich, has a pan mounted on this same principle, which Pohl states to be an adaptation of the principle of the salting-down pans of the alkali-makers. His arrangement, however, differs from that of Pohl in that the upper pan is dispensed with, being replaced by an arch of brickwork. According to Pohl's system of construction, the lower pan is 5 ft. deep. It may be made of boiler-plate or of cast-iron, or, for that matter, the bottom and lower parts of its sides might very well be made of elm or pitch-pine, with cast-iron ends and framing. Pohl tried brickwork for the construction of this lower pan, but abandoned it on account of leakage. In the pan figured, however, he has formed the bottom of tiles embedded in clay. Pillars of cast-iron rising from the bottom *i* of this lower pan support the upper pan, which is of the ordinary make, and demands no special description. The interval between the two need not, according to Pohl, be more than 3 in. In practice, however, 5–6 in. is not too much from the bottom of the upper pan to the surface of the brine in the lower one when completely filled. The length of these pans is about 60 ft.; breadth of the upper one, about 20 ft., and of the lower one, 22 ft., the space between the two being filled all around with brickwork. Milner has made the lower pan in his arrangement much wider than this, or rather it may be said a lip or opening running all along each side of the lower pan permits of the salt as it collects being drawn to the sides by rakes, and lifted out by perforated scoops as it accumulates. According to Pohl's arrangement, this might easily be managed by continuing the sides of his upper pan downwards for say 8–9 in., the pan being placed at such a height above the lower pan that these sides may dip 2–3 in. below the surface of the brine in the lower pan, and thus constitute a flue *f* 4–5 in. deep, through which the furnace gases might pass. The lower pan might then be made say 3 ft. wider than the upper one, so as to leave a trough on each side about 18 in. wide, through which the salt might be drawn. As it is, when the pan has to be drawn, which, of course, must be done as soon as it becomes full of salt, the fires have to be let out, the brine run off, and the salt drawn by the door or manhole, *k*, Fig. 1223.

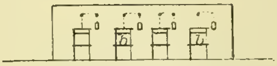
1219.



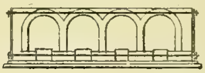
1223.

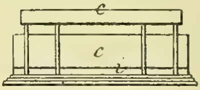


1224.

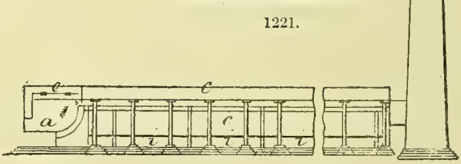


1222.





1221.



1220.

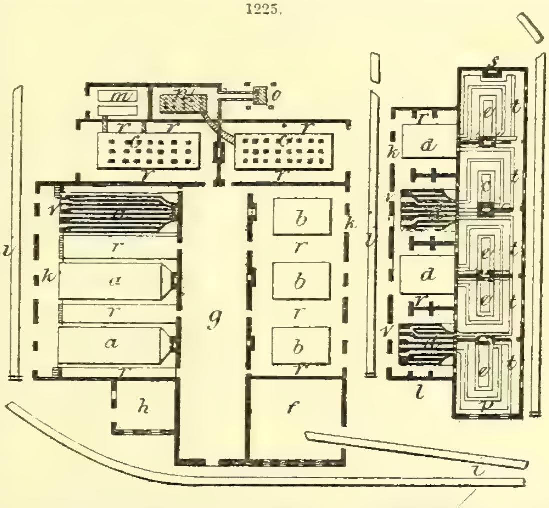
The furnaces in Otto Pohl's arrangement are four in number; they are made about 4 ft. wide internally, and 4½ ft. or even up to 6½ ft. between the top of the arch and the grate bars; a distance of 3 ft. or so is also left at the back between the end of the grate and the lower pan, the angle being filled up with a curve of masonry as shown at *e*, Fig. 1219. This form of construction is intended to allow space for more perfect combustion, before the heated gases enter between the pans, where they tend to become rapidly cooled, with proportionate liability to deposit soot. Fig. 1224 shows the front elevation and the arrangement of the sliding doors *b*. Pohl at first carried his upper pan right over the fires. He now stops short behind them, covering them in with arches of massive brickwork, so as to avoid as far as may be loss of heat by conduction in this quarter. He also proposed to make a sort of short circuitous flue, through which the products of combustion might be made to pass on their road to the space between the pans, by building three arches over the fires, constructed so as to reach alternately to the back and to the front of the fire-place, like the shelves of pyrites-dust kilns (see p. 84). These arches becoming strongly heated would aid in promoting the combustion of the smoke, while they served to catch the dust and ashes carried over from the fires. This plan, however, he appears to have abandoned. A further provision was made for getting rid of soot by keeping the lower pan always filled to the brim, making the end of it furthest removed from the fires a trifle lower than the fire end and sides, and keeping it full to the brim at that end. Much of the soot falling on the surface of the brine in light flocks, would float thereon, and be carried off over the end of the pan by the draught towards the chimney.

Between that end of the pan and the entrance to the chimney, is a soot-box or closet *h*, with a door for cleaning it out. Notwithstanding all these precautions, large quantities of soot are liable to become condensed, either upon the bottom of the upper pan, or between the two pans, and, falling on the surface of the brine, get carried down and mixed with the salt, rendering it black and totally unfit for food. This quality of salt, however, has been found specially suitable for the Hargreaves' salt-cake manufacture (see p. 287), so that the small quantities now produced find a ready enough sale, as the soot does not signify. The method shows an important economy of coal, and, according to Pohl, gives 3 tons of butter-salt with the same amount of fuel and labour as is requisite for producing 2 tons by the old methods. The use of gas from a Siemens' producer would obviate the soot completely, while it is probably preferable (according to Milner's plan) to do away altogether with the upper pan, employing merely a brick or tile covering as a reverberatory and radiating surface to throw the heat down into the lower pan, and so get rid of leakages, salt cats, and much cobbling and repairs involved in working by bottom heat. According to some experiments by Pohl, while the temperature of the upper pan remained suitable for making common salt, or ordinary fishery-salt, that of the surface of the brine in the lower pan was maintained at full boiling, and the produce, so far as grain was concerned, was very fine butter-salt, while no scale worth mentioning forms in the lower pan. He gives as a result of 16 days' boiling with brine containing 25·27 per cent. salt, for 57 tons of slack (from Little Houlton Colliery, Lancashire) burnt,—82 tons of fine butter-salt, and 49 of common salt; while on the old system, the 82 tons butter-salt would have taken 54 tons 13 cwt., and the 49 tons of common salt, 26½ tons, or a total of 81 tons 3 cwt., showing an economy of 24 tons 3 cwt. Instead of the gases escaping into the chimney at a temperature of 315° (600° F.), as during the manufacture of salt with the ordinary common salt pans, or at a temperature of 425°–538° (800°–1000° F.), as when making butter-salt, they never rose, even with the strongest firing, above 142° (288° F.).

Pohl states that in a subsequent trial, after lifting the top pan at the end nearest the fires to a height of 6 in., and lowering the other end to within 3 in. of the surface of the brine in the bottom pan, he obtained, as an average result of a series of boilings, 3 tons of salt for 1 ton of slack, the gases passing off at a still lower temperature; while in the top pan, 93°–98° (200°–208° F.) was the temperature attained in front, 82° (180° F.) in the middle, and 71° (160° F.) at the far end.

Fig. 1225 will serve to convey an idea of the usual arrangement of a salt-works, and will easily be understood from the foregoing descriptions. One of the fishery-salt pans *a* shows the disposition of the flues beneath, the outer flue on each side being called the "dead" flues. The spaces *r* throughout the building are pathways for the service of the pans and the "hurdles" on to which the salt is drawn. The fine salt-pans *d* have stoves *e* behind them, through which the flues circulate, and abut upon the chimneys *s*. Two of the fine-salt pans are shown with the dead flues on each side. At each end of the shed, and on each side of these fine-salt pans, are recesses in which the square and conical tubs used for moulding and draining the fine salt are kept ready to hand. The butter-salt pans *b* and fishery-salt pans *c* are heated respectively by the waste steam and waste heat of the fire gases from boiler and engine *n o*; *k* are the stoking pits of all the pans; *f* is the coal-store; *h*, the workshops for repairs; *g*, the salt-store; *i*, a railroad for the service of the works; *m* the offices.

1225.



The profits on salt manufacture in England are extremely small, owing to severe competition. In France, the saltmakers of each great region of production have constituted syndicates, by which the prices of salt and the scale of manufacture of each works are regulated, while they are protected from external competition by the peculiar conditions of the heavy excise duty, and the difficult formalities of the customs respecting imports of foreign salt. According to evidence given before the late Parliamentary commission, already referred to, the cost price of manufacturing common salt in the Winsford and Northwich district is about as follows:—Brine, 6*d*. a ton; labour, 10*d*.–1*s*.; coal (slack), 3*s*.; rent, interest on capital, &c., 1*s*.; total, 5*s*. 4*d*.–5*s*. 6*d*. a ton. These prices are subject to important variations. The cost of brine is always rated at so much per ton on the salt produced, and it varies for different works: at Northwich, for instance, 4–9*d.* per ton of salt is charged for brine; but 6*d.* may very well be adopted as a fair average price. The cost of coal likewise varies continually. The "burgey" used in making the boiled salts was, in the beginning of 1870, at 6*s.* 5*d.* a ton, rising to 9*s.* in 1872, and to 16*s.* and even 20*s.* in 1873. High prices continued till 1875, when they again began to recede, and, in 1878, ranged from 7*s.* to 8*s.*, falling in 1879 to 7*s.* 2*d.*–7*s.* 4*d.*, and in 1880 to 7*s.*–7*s.* 2*d.* The cost of the slack used in making common salt may be rated at about 1*s.*–1*s.* 6*d.* a ton below the prices of burgey. It is commonly admitted in Cheshire that an advance of 6*d.* a ton on slack means about 3*d.* a ton on common salt; and 6*d.* a ton on burgey, 4½*d.* a ton on boiled salts. The cost of carriage from the works to the canal on the banks of the Weaver also varies at the different works from nothing to 1*d.* and up to 4*d.* a ton.

It is thus difficult to fix any exact figure for the cost price of manufacture of salt in Cheshire, but the above may be taken as a near approximation in most cases. The carriage of the salt to Liverpool is performed in barges or "flats" on the Weaver; the selling price in the Liverpool market is 9*s.*, of which the works price is considered to be 5*s.* 6*d.*, and the official price of carriage 3*s.* 6*d.* To Runcorn, the carriage is 2*s.* 6*d.* The salt manufacturers may all be said to do their own lighterage, so that, as a matter of fact, any profits realized may be considered to be the 1*s.*–1*s.* 6*d.* gained on this score. The selling (i. e. the works) prices of salt in Liverpool (salt is rated there at present at the works prices), have been as follows:—The minimum price in 1871 was 6*s.* a ton; in 1872, prices varied from 7*s.*, 7*s.* 6*d.*, 10*s.* 6*d.*, to 17*s.*, and up to 20*s.*; in 1873, they were 14*s.*, 15*s.*, and down to 12*s.*; in 1874, they fell from 12*s.* to 8*s.*; in 1875, they kept nearly steady at about 9*s.*, falling however suddenly during one month of that year; in 1876, prices fluctuated from 8*s.* down to 5*s.*; in 1877, they even fell to 4*s.*, rising again to 7*s.*; in 1878, they were at 7*s.*, and fell to 5*s.* 6*d.*; in 1879, they again went as low as 4*s.* 6*d.*, running on into 1880 through 4*s.* 6*d.*, 4*s.* 9*d.*, to 6*s.* 6*d.*, and back to 6*s.* In the spring of the present year (1881), the works price was rated at Liverpool at 5*s.* 6*d.* for common salt. The salt manufacturers have repeatedly attempted to syndicate themselves after the manner of their Continental brethren, but as often their associations have been dissolved by disagreements springing up amongst them, at once entailing ruinous competition, and precluding all possible profits. The "Pool scheme," at one time in vogue in Liverpool, seemed to work satisfactorily for a short period. Under this plan, the works price was rated to the syndicate at 5*s.* 3*d.*, but the selling price was fixed and maintained at 8*s.* 3*d.*, 3*s.* being paid into a pool for the general *pro rata* profits of all. The plan, however, soon broke down through dissensions, and prices fell to ruinous rates. At the present moment, no saltmakers' association exists in England.

H. E. Falk furnishes the following list of salt exports from the Mersey:—

	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
The United States of America	182,939	153,206	222,612	176,885	212,532	215,100	223,346	216,258	256,920	261,687
British North America	94,382	67,634	59,869	56,024	54,807	58,103	65,918	71,624	78,171	109,836
West Indies and South America	9,130	6,704	5,616	6,343	4,442	5,815	6,522	5,860	9,404	14,064
Africa	22,685	19,438	21,784	26,747	25,507	23,132	24,580	24,513	20,610	35,475
East Indies	271,119	233,109	199,460	256,055	311,107	232,169	215.867	212,900	286,848	309,793
Australasia	9,192	9,792	17,208	12,309	24,918	13,908	20,564	15,600	13,517	24,474
Germany	38,495	34,310	35,716	28,394	32,474	43,618	28,804	23,479	22,844	37,859
Russia	40,591	50,762	70,496	61,802	49,200	73,893	49,991	43,232	42,452	41,177
Other Baltic and North Sea Ports	19,597	17,843	16,490	21,609	20,315	19,909	21,081	24,219	22,271	21,485
France and Mediterranean ..	1,898	1,130	1,706	2,243	889	1,055	1,680	1,053	809	2,381
Coastwise	91,720	71,608	54,614	51,533	72,268	66,555	47,530	44,604	33,045	39,087
Holland	18,339	19,384	19,653	27,400	23,652	22,102	20,107	19,204	18,922	18,910
Belgium	42,205	31,870	36,771	33,233	39,265	33,654	34,929	33,290	41,454	40,493
Export from Liverpool	842,292	716,790	761,995	760,577	871,376	809,013	76,019	735,836	847,267	956,721
Export from Runcorn and Weston Dock	213,435	166,583	148,956	177,958	161,111	173,614	182,638	233,668	239,583	244,785
Total from the Mersey ..	1,055,727	883,373	910,951	938,535	1,032,487	982,627	943,557	969,504	1,086,850	1,201,496

The Director-General of the French Customs has kindly furnished the following table of quantities of salt produced in France during the last 7 years (in French tons of 2204 lb.):—

Years.	Sea Salt.		Saltworks of the N.-E. and S.-W. White Salt (1).	Total.
	Mediterranean.	Atlantic Coast.		
1874	255,303	253,800	229,459	738,562
1875	195,965	177,666	230,063	603,694
1876	168,384	157,059	252,050	577,493
1877	293,047	(2) 44,526	252,833	590,406
1878	283,727	(2) 29,020	258,237	570,984
1879	240,577	(2) 3,039	213,471	457,087
1880	286,685	78,358	239,404	604,447

(1) In this column, the make of the S.-W. saltworks may be estimated at 10,000–11,000 tons.

(2) The rains and floods rendered the production of the Atlantic coast almost nil during the years 1877, 1878, and 1879.

The author desires to express his indebtedness to Messrs. Blades, Falk, Ward, Wigner, Botta of Nancy, and Archibald of Florence, for many valuable details and figures. F. M. L.

SILK (Fr., *Soie*; Ger., *Seide*).

The term "silk" is employed to denote the fibrous material produced by a number of insects for the purpose of forming a "cocoon" or nest in which a certain period of their existence is passed. The material composing this fibre is called "serisine," and is a product of the insect itself, exhibiting slight variations according to the species, and according to the food. It is the strongest, the most lustrous, and the most expensive of all organic fibres.

Raising.—Hence, the cultivation of the worms which produce the fibre has attracted attention from time immemorial, and silk-raising is one of the most profitable industries that can be undertaken in suitable climates. The first step in sericiculture is to secure a supply of food for the worms. For this purpose, the leaves of the mulberry seem to be unequalled. There are many species and varieties from which to choose, and preference should always be given when possible to that whose leaves afford the best sustenance to the worms, as indicated by their own predilections. Spotted and mildewed leaves must be avoided, and great care must be taken that the leaves are supplied fresh, dry, and clean, and particularly not heated or fermented. The points to be borne in mind in arranging a *magnanerie* or silkworm nursery are as follows:—A free circulation of air, without draughts, the windows never being opened on the windward side, except in the tropics; plenty of light, but no actual sunshine in hot climates; avoidance of all scents and odours, whether pleasant or otherwise, and of all noise; the temperature and moisture of the atmosphere of the chamber must be carefully watched and regulated. Electrical disturbances induce a kind of dysentery or cholera in the worms, which disease can only be stamped out by killing all the afflicted worms and all those which have been in contact with their excreta, as well as removing all excreta-stained leaves, nets, &c. Another disease, which has become a serious epidemic, is immediately caused by a fungus, called *Panhistophyton*; its germs may be discovered as microscopic cylindrical corpuscules in the blood of infected worms. Hence the necessity for thorough microscopic examination of every pair of moths before their eggs may be considered sound. The examination may be made after the moths are dead and dried, by grinding them into a paste with a little water.

This system of microscopic selection should be rigidly adhered to. Before removing the silk from the cocoon, it is necessary to kill the chrysalis inhabiting it. This may be done by placing it in an oven at a temperature not exceeding 93° (200° F.); but a much superior plan is to subject it for a few minutes to dry steam, which has a cleansing action upon the silk, and does not at the same time make it brittle.

The silk of which the cocoon is formed is one solid thread of great length (even 500 yd.), which has been wound from the outside towards the centre, and diminishes in size as it proceeds, till reduced to $\frac{1}{3}$ or $\frac{1}{4}$. It is detached and prepared for use by a process termed "reeling." There is always a certain portion left which cannot be reeled; this may be carded and spun. With this object, large quantities of "husks" or "knubs," as the waste cocoons are called, are exported to Europe from the great silk-growing countries of the East, and the product thus obtained is known as silk "waste." Reeling is an operation requiring considerable practice and skill for its proper performance. There are several handy machines in the market for the purpose, and choice should be made of one of slow motion for beginners.

It may be useful to state that Chinese silk, by far the most important commercially, is put up in bales of the following weights:—Fine raw silk, 80 *catties* (of $1\frac{1}{3}$ lb.); raw wild silk, 1 *picul* (of $133\frac{1}{3}$ lb.); hydraulic-pressed waste silk, 2 *piculs*; cocoons, $1\frac{1}{2}$ *piculs*.

Production and Commerce.—The silk production of Europe may be approximately estimated at 9 million lb. yearly, while Asia affords an additional 11 million lb. for export to European markets. The chief contributors to this enormous total of 20 million lb. are as follows:—China, 8 million lb.; Italy, $6\frac{1}{4}$; France, $1\frac{1}{4}$; Japan, $1\frac{1}{4}$; Turkey, $1\frac{1}{4}$; India, 1; Persia, Georgia, &c., 1. Some remarks upon the silk industry of each of these countries will now be given in the order just stated.

China.—The total silk production of China is officially stated at about 23,232,000 lb. annually, of which, some 16,588,000 lb. is afforded by cultivated mulberry worms (*Bombyx mori*), 1,364,000 lb. by wild worms on mulberry and other trees (*B. mori*, *B. atlas*, &c.), 660,000 lb. is raised from the ailanthus worm (*B. cynthia*), and 4,620,000 lb. from oak-feeding worms (*B. Pernyi* and *B. mylitta*). It will be convenient to consider each province under the head of its treaty port.

1. Newchwang.—The raw silk grown for export in Sheng-king is entirely from *B. Pernyi* [*Fantoni*], fed on the leaves of *Quercus mongolica* [*robur*]. The silk regions of this province are two:—A tract of 80 × 150 miles lying E. of the Liao River, the home of *B. Pernyi*; and a large portion of Liaohsi, scantily producing *B. cynthia.* In the former, one valley affords 12,000 cub. ft. of cocoons, and the yield throughout the district could be increased tenfold by planting the hill-sides with oak-shrubs. As reeled by the natives, the silk contains 20 per cent. of gum, and the excess of soda used to remove it decreases the value of the fibre for export; but properly reeled, it boils white, takes any dye, and can be used for tram. Native reeling gives 1 lb. silk from 10 lb.

cocoons. In water-reeling, the cocoons are placed in an iron pot with crude, strong, native soda, and covered with water; when the gluten has dissolved, the threads of 8–10 cocoons are caught up together and reeled off. By the dry-reeling system, the cocoons are first boiled in strong alkaline solution, and then reeled from a table at *uso doppio.* The chrysalids are killed by steaming 2500 at a time in small baskets. The silk of spring cocoons is much less in quantity than from autumn, but much whiter and finer in quality. A black silk is produced near Kaichow by *B. Pernyi*, where it devours the petiole, ribs, and veins of the oak-leaves. The cocoons of the district give an average of 500 *mètres* of silk, a weight of 0·432 *grm.*, and a "title" of 7440 *deniers.* Scarcely any disease is known among the hardy worms of Manchuria, and they have been recommended for restoring the worn-out European race. They are fed only on *Q. mongolica* when obtainable, but failing this, on *Q. castaneæfolia* and *Q. dentata.* These trees are all pruned back to 5–6 ft. high. The exports of raw silk from Newchwang in 1879 were 60 *piculs* (of $133\frac{1}{3}$ lb.) of wild.

2. Tientsin.—Silk-culture in Chihli, Shansi, and Honan is of small importance. Chihli annually produces about 300 *piculs* of cultivated and 700 of wild silk; of the former, about $\frac{4}{10}$ is yellow and $\frac{6}{10}$ white. Shansi only yields about 700 *piculs* of raw silk yearly, 500 being wild. Honan yearly affords about 6000 *piculs* of white and 1000 of yellow cultivated silk, and 3000 of wild.

3. Chefoo.—The annual production by worms fed on mulberry-leaves is about 80 *piculs* of white and 1024 of yellow raw silk; that of worms fed on ailanthus, about 6 *piculs*; that of worms (2 kinds) fed on oak-leaves, 7125 *piculs* of wild raw; that of wild mulberry-feeding worms, 15 *piculs.* The exports from Chefoo in 1879 were 1000 *piculs* of yellow, 750 of waste, and 500 of raw silk.

4. Ichang.—The average yearly production of raw silk from mulberry-feeding worms is 2000 *piculs* in Hupeh, 10,000 in Szechuen, and 400–500 in Kweichow; by wild worms frequenting mulberry-trees, about 1000 *piculs* in Kweichow. The exports from Ichang in 1879 were 750 *piculs* of yellow Szechuen and 18 of white ditto.

5. Hankow.—The total raw silk grown in Hupeh is estimated at 6000 *piculs* annually, and in Szechuen at 15,000, of which only about $\frac{1}{10}$ is white. The exports from Hankow in 1879 were 7000 *piculs* of raw Szechuen, 425 of white, 425 of cocoons, and 150 of refuse.

6. Kiukiang.—A very small quantity of raw silk is produced in the northern part of the province of Kiangsi, but the quality is inferior, and none is exported. The worms are fed on mulberry-leaves.

7. Wuhu.—Of the raw silk produced in the province of Anhwei, the colour is somewhat inferior and the quality coarse. The average yearly quantity is 600–800 *piculs* from worms fed on mulberry-leaves. The export in 1879 was 400 *piculs* of raw silk.

8. Chinkiang.—Domestic worms are reared on mulberry-plants. These latter are of two kinds, wild and cultivated. The wild kind is sturdy in growth, but has thin small leaves, so the general practice is to graft the cultivated variety upon it. The plantations are made on high plains. The trees are pruned back to a height of little over 5 ft. They are liable to the attacks of two insects, one penetrating below the bark, the other not. The former is detected by a greasy exudation from the bark; the place is cut open, and the larvæ are destroyed, or, if they have already become insects, they are killed by the insertion of a wire or the introduction of wood-oil into their holes. The second kind attacks the leaves; it is destroyed by sprinkling the trees with a strong solution of the juice of tobacco-stalks. The wild mulberry is neither grafted nor pruned, the largest trees reaching a height of 50–60 ft. The silk of worms fed on the wild mulberry is very coarse and inferior. Worms that have once tasted cultivated leaves will not eat wild ones. There are ten precepts observed in breeding the worms:—(1) The eggs when on paper must be kept cool; (2) after hatching, they require warmth; (3) during moulting, they must be kept hungry; (4) between their sleeps, they must be well fed; (5) they should be neither crowded nor too far apart; (6) during sleep, they should be kept dark and warm; (7) when their skins are cast, they need coolness and plenty of light; (8) for a short time after moulting, they should be sparely fed; (9) when fully grown, must never be without food; (10) the eggs should be laid close together but not heaped up. It may be added that smoke, draughts, and smells of all kinds are injurious to the worms, and great care needs to be taken that the leaves shall always be fresh, dry, and quite clean.

The worms, as fast as they are ready for weaving their cocoons, are transferred to hills made, of straw. Any that are black or putrid are discarded. When the spinning is finished, the cocoons are removed, freed from the loose silk around them, and spread out on large trays in a cool spot. Flossy, maggot-bitten, sick, misshapen, urine-stained, and double cocoons are carefully picked out, as being unfit for reeling. The hardest, cleanest, and whitest cocoons are reserved for breeding purposes.

Wild worms are fed on *Quercus sinensis*, *Q. serrata*, and *Q. mongolica.* The last is 5–6 ft. high, and is grown around the villages for its leaves. The silk produced by it is hard. Two crops of cocoons are gathered annually from wild worms. They are smaller than the domestic ones, and of greyish-black colour.

9. Shanghai.—In the province of Chiangsu, the average quantity of raw silk produced for export from worms fed with mulberry-leaves is about 500,000 lb.; and in the province of Chêhchiang, about 6,500,000 lb. The product from wild worms frequenting mulberry-trees is about 4000 lb. The exports from Shanghai in 1879 were 60,350 *piculs* of raw, thrown, and yellow, 620 of wild raw, 6134 of refuse, and 1888 of cocoons; the exports are mainly destined for France, India, and Great Britain.

10. Ningpo.—The production of raw silk by worms fed with mulberry-leaves is about 6,500,000 lb.; and by wild worms found on mulberry-trees, 4000 lb., only in the district of Sharanglin. The export in 1879 was 350 *piculs* of raw silk.

11. Canton.—The average production of raw silk in this district may be stated as follows:—Exported to Europe, 12,000–14,000 bales (of 213 lb.); to Bombay, 3000–4000 *piculs*; to America, 10,000 boxes (of 150 lb.); and produced for native use, 20,000 *piculs*. This is exclusively afforded by worms fed upon mulberry-leaves. There is also a kind of raw silk spun by a worm frequenting the leaves of the camphor and kindred trees, not only on the Lofou Hills, but generally throughout the province of Kwangtung, though nowhere very abundantly. It is not cultivated, and very little silk is obtained from it, its chief use being for making "gut" (see p. 610), for which purpose, it is considered superior to the mulberry worm. The exports from Canton in 1879 were 16,200 *piculs* of fine raw silk, 130 of thrown, 7500 of refuse, 3500 of wild raw, and 2000 of cocoons.

12. Kiungchow.—The annual production is about 280 *piculs* of raw silk from worms fed on mulberry-leaves. There is also an average yearly production of 120 *piculs* of gut from a large caterpillar found on a tree growing in the centre of the island of Hainan, and supposed to be *Liquidambar formosana*. The export of raw silk in 1879 was 230 *piculs*.

13. Pakhoi.—The "gut"-yielding worm largely frequents the *Liquidambar* trees in this neighbourhood.

Our imports from China of raw silk fell from 4,984,800 lb. in 1876, to 3,165,935 lb. in 1880; while knubs, husks, and waste rose from 10,936 cwt. in 1877, to 31,402 cwt. in 1880. The approximate London market values of Chinese raw silks are:—16–19*s.* a lb. for Tsatlee No. 3, 11–16*s.* for Nos. 4, 5, &c., 9–18*s.* for Taysaam, and 10-16*s.* for Canton.

Italy.—Preference is given to the white mulberry (*Morus alba*) both in Italy and France for feeding silkworms. Great care is generally taken in carrying out Pasteur's method of microscopic selection of the moths in all large establishments. As to the yield of the different breeds, 1 oz. Japanese grain gives 35–45 lb. green cocoons; 1 oz. Japanese reproduced in Italy, 85–95 lb. green; 1 oz. Italian green, 130 lb. yellow; 1 oz. French striped (Var), 78 lb. nankin; 1 oz. Roussillon, maximum 175–190 lb. roseate-yellow. In 1879, about 80,000 cards of grain were imported from Japan, about 10 per cent. remaining unsold. In many districts, the cultivation of Japanese grain is almost nil, attention being exclusively paid to Italian grain yielding yellow cocoons giving a satisfactory product. In Lombardy, in 1879, a large proportion of the grain cultivated consisted of reproductions of green and crossed white and green Japanese breeds, while experiments on an augmented scale were made in cultivating the native yellow grain. In Piedmont, a certain quantity of grain imported from France and producing yellow cocoons was cultivated in addition to the Japanese varieties. In Venetia, the larger portion of the yield was composed of imported Japanese grain and Italian reproductions, the native grain forming but a small item. In Emilia, the yield was ¾ native and ¼ Japanese, either imported or reproduced in Italy. In Tuscany and the Marche, the bulk of the yield was from native grain giving yellow cocoons. The total yield of cocoons in Italy in 1879 was as follows:—

Region.	Yield.	Value.
	Kilo.	Lire.
Piedmont	4,155,618	20,670,631
Liguria	55,000	297,000
Lombardy	6,325,299	31,733,150
Venetia	3,569,439	19,627,023
Emilia	1,470,688	8,186,660
Tuscany	610,562	3,819,036
Marche, Umbria, Comarca	1,172,168	6,995,717
Neapolitan Provinces	1,413,775	5,802,564
Sicily	167,500	703,500
Sardinia	..	..
Total	18,940,049	97,835,281

Of this total, about 5½ million *kilo.* of cocoons were yellow, and 13½ million green. The production of raw silk was computed at 499,938 *kilo.* yellow, and 960,052 green. The exports from Naples in 1879 were 8753 *kilo.* of cocoons, 698 of raw silk, and 26,476 of waste; the values of the silk exports were 6286*l.* to Great Britain, 19,612*l.* to France, 440*l.* to Germany, 515*l.* to Turkey and Egypt, and 518*l.* to other countries. Our imports of raw silk from Italy fell from 24,552 lb. in 1876, to 36 lb. in 1877, and recovered to 36,643 lb. in 1880; of waste, knubs, and husks, from 155 cwt. in 1876, to 0 in 1878, and 84 cwt. in 1880. The approximate London market values of Italian silks are 24–26*s.* a lb. for Novi raw white, 22–28*s.* for Milan thrown, and 25–30*s.* for Piedmont thrown.

France.—The number of silk growers in France in 1874 was 198,043, 64,957 of these being on a large scale. Yet while France exported only 4,737,000 *kilo.* of raw and waste silk in 1879, she imported in the same year 10,889,000 *kilo.* The production is almost exclusively from cultivated worms fed on mulberry-leaves, but attention is being gradually given to the introduced ailanthus worm. There has hitherto been great difficulty in rearing the silk-worms *Attacus Yama-maï* and *A. Pernyi*, and other species feeding on oak-leaves, in Europe, on account of the early date at which the leaves are required. Much importance is therefore attached to the introduction of *Quercus Mirbeckii* from Algeria into S. France, as this species (or variety) develops its leaves in March, being fully a month in advance of all French oaks. Calais, in 1879, exported 1832 *kilo.* of raw and thrown, and 1769 of waste silk. Our imports from France of recent years have seen the following fluctuations:—Raw rose from 242,706 lb. in 1876, to 566,522 in 1877, and fell to 81,361 in 1880; waste, knubs, and husks fell from 9323 cwt. in 1876, to 6514 in 1877, and recovered to 14,169 in 1880; thrown fell from 144,660 lb. in 1876, to 32,033 in 1878, and reached 192,932 in 1880.

Japan.—The silk of Japan is produced almost entirely by cultivated worms fed on mulberry-leaves, several species of mulberry being grown for the purpose; but a certain and increasing quantity is afforded by *yama-maï* worms feeding wild on oak-trees, a hardier and more prolific race. Silk-growing is pretty universal in Japan, and has been greatly stimulated of late years, but there is room for much improvement in the reeling and other operations. Microscopic selection and machine-reeling are gaining ground. Our imports of Japanese raw silk fell from 448,541 lb. in 1877, to 240,326 in 1880; and of knubs, husks, and waste, rose from 470 cwt. in 1877, to 2577 in 1880. The approximate London market value of Japanese raw silk is 14–19*s.* a lb. for ordinary, and 16–21*s.* for fine to superior.

Turkey.—In Asiatic Turkey mulberry-trees grow almost everywhere, but are mainly utilized for silk and cocoons in the district of Broussa, the neighbourhood of Diarbekir, N. Syria, and the Lebanon. A species of wild silk called *gez* and *jel*, grows extensively in Kurdistan, between Zacho and Rowandooz, but although much prized and worked by the Kurdish women, it has not yet found its way into Western commerce. The export of the raw material and of cocoons from Broussa averages in value about 350,000*l.* a year. The cultivation round Diarbekir is less developed, but there also the soil and climate are excellently adapted to its pursuit on a large scale. In Syria, it rivals tobacco as a local staple; and in the lower and middle ranges of the Lebanon, employs a large number of hands. In all these centres of silk culture, the best filament is produced from Japanese eggs, but fraudulent substitutions for these have greatly damaged the quality of Turkish silk, and correspondingly affected the industry both at Broussa and in Syria. The silkworm disease has been very bad for the last three years, and has caused the production of high-quality silk to fall off very much, the silk produced from the seed brought from Japan and other countries being far inferior to the produce of native silkworms. These latter are described as yielding cocoons quite white in colour, and more than double the size of the yellow cocoons made by the Japanese worms. An opinion is prevalent that the disease will pass away in time, when it will be possible to return to the production of silk from native worms only. The exports in 1879 from Musyna were 15 tons cocoons, value 1650*l.*, to Turkish ports, and 1 ton, 120*l.*, to England; from Alexandretta, 10 tons cocoons, 6000*l.*, to France, 1 ton, 600*l.*, to Austria, 2 tons, 1200*l.*, to Turkish ports; from Dedeagatch, 800 bales cocoons, 20,000*l.*, and 150 bales silk waste, 800*l.*; from Trebizonde (Persian produce), 429 bales (of 1½ cwt.) of silk, 42,900*l.*, to Turkish ports, 55 bales (of 1¾ cwt.) of waste silk, 825*l.*, to Turkish ports, and 41 bales, 645*l.*, to France. Our imports from Turkey in Asia of raw silk fell from 5610 lb. in 1877, to 0 in 1879, and recovered to 520 lb. in 1880; of waste, knubs, and husks, 153 cwt. in 1876, 58 in 1877, 2027 in 1878, 688 in 1879, and 69 in 1880. The approximate London market value of Broussa silk is 24–29*s.* a lb.

Our imports of raw silk from Turkey in Europe were 4210 lb. in 1877, 784 in 1878, and 5821 in 1880; of waste, knubs, and husks, 362 cwt. in 1877, 94 in 1878, and 356 in 1880. Thessaly, in 1880, exported 20,000*l.* worth of silk and cocoons.

India.—Perhaps no country in the world is so rich in indigenous silk-producing insects as India. This is sufficiently indicated by the following list, arranged by F. Moore, curator of the India Museum:—

1. Mulberry-Feeding. *a.* Domesticated.—*Bombyx mori*, the common silkworm, domesticated in

China, Japan, Bokhara, Afghanistan, Cashmere, Persia, S. Russia, Turkey, Egypt, Algeria, Italy, France, and Spain, producing but one crop annually, spinning the largest cocoon and the best silk, of a golden-yellow or white colour. *B. textor*, the *boro poolloo* of Bengal, domesticated in S. China and Bengal; annual only; a white (sometimes yellow) cocoon, of a different texture and more flossy than *B. mori*. *B. sinensis*, the *sina*, *cheena*, or small Chinese monthly worm of Bengal, partially domesticated in Bengal, where it was introduced from China; several broods in the year, cocoon, white and yellow. *B. crœsi*, the *nistry* or *madrassee* of Bengal, introduced from China; domesticated in Bengal; 7–8 broods of golden-yellow cocoons in the year, of larger size than *B. sinensis*. *B. fortunatus*, the *dasee* of Bengal; several broods annually; the smallest cocoon, of a golden-yellow colour. *B. arracanensis*, the Burmese silkworm, domesticated in Arracan, said to have been introduced from China, through Burma; several broods annually; cocoons larger than the Bengal monthly species.

b. Wild.—*Theophila Huttoni*, the wild silkworm of the N.-W. Himálayas; worms found abundantly feeding on the indigenous mulberry in the mountain forests. *T. sherwilli*, the wild silkworm of the S.-E. Himálayas. *T. bengalensis*, the wild silkworm of Lower Bengal; in the neighbourhood of Calcutta feeding on *Artocarpus lacoocha*; also at Ranchee in Chota Nagpore. *T. religiosa*, the *joree* of Assam and *deo-mooga* of Cachar; feeds on the *bur* tree (*Ficus indica*) and the *pipul* (*F. religiosa*). *T. mandarina*, the wild silkworm of Chekiang, N. China; stated to feed on wild mulberry-trees, spinning a white cocoon. *Ocinara lactea*, at Mussooree, N.-W. Himálaya; feeds on *Ficus venosa*; small yellow cocoon; several broods during the summer. *O. Moorei*, at Mussooree, N.-W. Himálaya; also feeds on *Ficus venosa*, as well as on the wild fig; a small white cocoon; multivoltine. *O. diaphana*, on the Khasia hills. *Trilocha varians*, in N. and S. India.

2. Atlas and Eria Group.—*Attacus atlas*, in China, Burma, India, Ceylon, Java; almost omnivorous, feeding in different districts upon the shrubs and trees peculiar to it, as *Bradleia ovata*, *Falconeria insignis*, and several other trees at Mussooree; the yellow flowering barberry at Almorah; and various other trees at Cachar; cocoon well stored with a fine silk. *A. silhetica*, in Silhet. *A. Edwardsia*, in Sikkim, Cherra, and Khasia hills. *A. cynthia*, in China; domesticated in the provinces of Shantung and Honan; feeds on *Ailanthus glandulosa*. *A. Ricini*, the *eria* of Assam, and *arindi* of Dinajpore; domesticated in the N. parts of Bengal (Bogra, Rungpore, and Dinajpore), in Assam and Cachar; feeds on the castor-oil plant (*Ricinus communis*); seven or more crops annually; cocoons somewhat loose and flossy, orange-red, sometimes white. The so-called "Ailanthus silkworm" of Europe—the result of a fertile hybrid between the Chinese and the Bengal species—was produced some years ago in France, whence it was introduced into various parts of the world. *A. Canningi*, in the N.-W. Himálayas; common in a wild state, feeding on the leaves of *Coriaria nipalensis* and *Xanthophyllum hostile*; cocoons hard and compactly woven, rusty-orange or grey; annual. *A. lunula*, in Silhet. *A. obscurus*, in Cachar; not very common; stated to feed on a plant called *lood*. *A. Guerini*, in E. Bengal.

3. Actias Group.—*Actias Selene*, in Mussooree, Sikkim, Khasia hills, and Madras; feeds upon *Andromeda ovalifolia*, *Coriaria nipalensis*, wild cherry, and walnut, at Mussooree, and on *Odina Wodier* in Madras. *A. sinensis*, in N. China. *A. Leto* and *A. Mœnas*, in Sikkim and Khasia hills. *A. ignescens*, in the Andaman Isles.

4. Tusser and Moonga Group.—*Antherœa mylitta* [*paphia*], the *tusser*, *tasar*, or *tussah* silkworm; well-known and valuable insects (of various undetermined species), widely distributed over India, from E. to W. and N. to S., on the coast, and in the Central Provinces; feed in a wild state upon the *ber* (*Zizyphus jujuba*), the *asun* (*Terminalia alata*), the *seemul* (*Bombax heptaphyllum*), &c. *A. Mezankooria*, the *mezankoorie* silkworm of the Assamese; stated to feed on the *addakoory* (? *Tetranthera quadrifolia*), which is abundant in Upper and Lower Assam; silk nearly white, its value being fifty per cent. above that of the *muga*. *A. nebulosa*, the *tusser* of the Sonthal jungles of Colong; also found in Singbhoom, Chota Nagpore. *A. Perrotteti*, in the districts of Pondicherry, feeding upon a species of *Zizyphus*, the *jambool* (*Syzygium jambolanum*), &c.; four broods in a year. *A. andamana*, allied species to the tusser, in the S. Andamans. *A. Frithi*, in Sikkim and the Himálayas; common, wild, inhabiting the hot subtropical valleys below 2000 ft.; cocoon is stated to be similar to tusser in form, but finer silk. *A. Helferi*, in Sikkim and the Himálayas; a common species in the hot valleys of Sikkim. *A. assama*, the *moonga* or *muga* of the Assamese; feeds upon the *champa* (*Michelia sp.*) the *soom* (? *Tetranthera lanceolata*), *kontoolva*, *digluttee* (*Tetranthera diglottica*), the *pattee shoonda* (*Laurus obtusifolia*), and the *sonhalloo* (*Tetranthera macrophylla*); extensively cultivated by the natives, and can be reared in houses, but is fed and thrives best in the open air and upon the trees; the silk forms an article of export from Assam, and leaves the country generally in the shape of thread. *A. Roylei*, the oak-feeding silkworm of the N.-W. Himálayas; common on the hill-oak (*Quercus incana*) of the N.-W. Himálayas (Simla, Masuri, Almora); cocoon large and very tough; silk pronounced as promising, and worth cultivating; can be reared easily in the house.

5. Miscellaneous Group.—*Salassa Lola*, Sikkim, Himálayas. *Rinaca Zuleika*, Sikkim. *Rhodia Newara*, Nepal (Kathmandoo); feeds upon a species of weeping willow; brilliant green cocoon,

pendant from the twigs. *Caligula thibeta*, Mussooree, N.-W. Himálayas, 7000 ft.; common, feeding on *Andromeda ovalifolia*, wild pear, and cultivated quince; light, open, net-like cocoon. *C. simla*, Simla, N.-W. Himálayas, 5000 ft.; feeds on the walnut, *Salix babylonica*, wild pear, &c.; open, net-like cocoon. *C. cachara*, Cachar. *Neoris Huttoni*, Mussooree, N.-W. Himálayas, 6500 ft.; worms appear in April, feeding upon a species of wild pear tree; thin silken cocoon. *N. shadulla*, Yarkand. *N. Stoliczkana*, Ladak. *Saturnia cidosa*, *S. Grotei*, *S. lindia*, and *S. anna*, hot valleys of the Sikkim Himálayas. *Loepa katinka*, Sikkim, 5000–7000 ft., Assam. *L. sikkima*, hot valleys of Sikkim. *L. sivalica*, Mussooree, 5000 ft.; long cocoon, pointed at each end, and of a dark greenish-grey colour. *L. miranda*, Sikkim, Himálayas. *Cricula trifenestrata*, the *haumpottonee* of the Assamese; very common in Assam; feeds on the *soom*; open net-like cocoon, of a beautiful yellow colour, and of a rich lustre, the silk being spun in the same manner as the *eria* cocoon; occurs also in Moulmein, where the worms are stated to feed upon the cashew-nut tree (*Anacardium orientale*). *C. drepanoides*, Sikkim. A few others which are well worth the attention of the Government of India for the purpose of acclimatization there are :—*Antheræa Pernyi*, the oak-feeding silkworm of Manchuria, N. China, described as having been long known to the Manchu Tartars, very large quantities of the silk being used among the Chinese; feeds on various species of oak (*Quercus mongolica*), &c., the cocoon differing from the tusser in form and texture; silk represented as strong, but with little lustre; two crops in the year—spring and autumn. *A. Confuci*, allied to *A. Pernyi*, inhabiting the hills in the neighbourhood of Shanghai, N. China. *A. Yama-mai*, the *yama-mai* silkworm of Japan; oak-feeding; cocoon of a pale yellowish-green colour; excellent silk of considerable commercial value in Japan; has been acclimatized in Europe, and, crossed with *Bombyx Attacus Pernyi*, is successfully reared in France, the eggs hatching at almost freezing-point. *Saturnia pyretorum*, S. China; feeds upon the *Liquidambar formosana* in Canton, Amoy. *Neoris shadulla*, Yarkand. *Theophila mandarina*, N. China.

The most important of the wild silks of India is the *tusser* (very variously spelt), or *Antheræa paphia* (with about a dozen synonyms). The worms feed indiscriminately on *Rhizophora calceolaris*; *Terminalia glabra* (the *assum*), *T. tomentosa* (the *saj*), and *T. catappa* (the country almond); *Tectona grandis* (teak); *Zizyphus jujuba* (the *ber*); *Shorea robusta* (the *sal*); *Bombax heptaphyllum* (the *semul*); *Careya sphærica*; *Pentaptera tomentosa* and *P. glabra*; *Ricinus communis* (castor-oil); *Cassia lanceolata*. The cocoons are curiously suspended from the branches of the trees. The insect is distributed over nearly the whole of India. In the Central Provinces, the silk is utilized in Rajpore, Bilaspore, Sumbulpore, the Upper Godavery, Chanda, Bhundora, Nagpore, Balaghab, Seonee, Chindwara, Betool, and Nursinghpore. Sumbulpore is said to yield yearly 7000 lb. of the silk; Rajpore, 12,000 lb.; Bilaspore, 1800 lb.; Chanda, 45,000 lb. Major G. Coussmaker, who has done so much to establish the domestic cultivation of this worm in the Deccan, finds that it thrives well on *Lagerstrœmia indica*, and still better on *Carissa carandus*; the former resumes thick foliage within a fortnight after having all its leaves eaten off. The filament of this kind of silk is of tape-like form, and not cylindrical as is commonly the case.

The *eria* worm is so called from the Assamese name of the castor-oil plant (*Ricinus communis*), on which it is almost exclusively fed. It is reared entirely indoors. The duration of its life varies with the season: in the summer, it is shorter, and the product is both better and more abundant. At this season, 20–24 days elapse from the date of its birth to the time when it begins its cocoon, 15 days later the moth is produced, in three days the eggs are laid, and in five more they are hatched, making the total duration of a breed 43 days. In winter, its life extends to nearly two months. Seven broods are reckoned upon annually. When the worms have ceased feeding, they are placed in baskets filled with dry leaves, amongst which they form their cocoons. In four days, the latter are complete. A selection having been made for the next breed, the remainder are exposed to the sun for 2–3 days, to destroy the vitality of the chrysalis. The cocoons are next generally put into water containing potash (wood-ashes), over a slow fire; when removed, the water is gently squeezed out. At other times, they are massed together for some days with *amrita* (? *Carica papaya*) or *madhu* fruit. The object is the same in either case, viz. to facilitate the drawing of the silk. It is coarse, and none of it ever finds its way into Bengal.

The *muga* moth is found wild in the jungles of Assam, but all the silk produced by it is from domesticated worms. They are reared on trees in the open air. There are generally five breeds in a year, viz. January–February, May–June, July–August, September–October, and November. The first and last yield the best crops, as regards both quantity and quality. Constant watching of the trees is necessary. The worms thrive best in dry weather, but a very hot sunny day at the moulting time proves fatal to many. Indeed, at this period, rain is considered very favourable; and even thunderstorms are not injurious, as they are to the mulberry worm. Continual heavy rains do mischief by sweeping the worms off the trees; but showers, however violent, cause no great damage, the worms generally taking shelter under the leaves with perfect safety. The total duration of a breed varies from 60 to 70 days. The chrysalis not being easily killed by exposure to the sun, a number of cocoons are placed upon bamboo stages, and covered with leaves, whilst a quantity of dry grass is ignited below them, and in a short time destroys them. The cocoons are then boiled for about an hour in water containing potash (the ashes of mustard and other plants). When taken out, they are laid between folds of cloth. The floss is removed by hand, and the cocoons are thrown into hot water. The instrument used for winding off the silk is the roughest imaginable. The Assamese consider it a good annual return if an acre of trees support 50,000 cocoons, yielding upwards of 24 lb. of silk. It must be very profitable, as 1000 cocoons are reckoned to afford 6–8½ oz. of silk thread, selling at 10–12*s.* a lb. The labour and expense of maintaining a plantation of the trees is very trifling. Lakhimpur, in 1871, exported 11¼ tons of *muga* silk thread, value 6090*l.*

The *mujankuri* (variously spelt) worm is really a variety of *muga*, feeding on the *mujankuri* or *adakuri* plant (*Tetranthera polyantha*). The silk is whiter and better, some of the thread produced in Sibsagar selling for 36*s.* a lb. It is rarely in the market.

The exports of Indian raw silk were 1,656,015 lb., value 766,462*l.*, in 1875; and 1,329,599 lb., 570,229*l.*, in 1879. Our imports of Indian raw silk fell from 150,232 lb. in 1876, to 105,006 lb. in 1880; and of knubs, husks, and waste, from 4396 cwt. in 1877, to 3404 cwt. in 1880. The approximate London market values of Indian raw silks are as follows:—Radnagore, 10–16*s.* a lb.; Surdah, 14–18*s.*; Gonatea, 11–17*s.*; Cossimbuzar, 11–17*s.*; Comercolli, 10–16*s.*; Hurripaul, 8–10*s.*; Jungypore, 11–15*s.*

Persia.—The exports of Persian silk, the produce of Ghilan, to Russia, in 1879, were 109,600*l.* worth of raw, 16,150*l.* husks, 1150*l.* cocoons. The exports of silk viâ Gez were 200 ballots, value 9230*l.*, from Asterabad, and 400, value 27,690*l.*, from Khorassan and Subzevar; while the refuse amounted to 400 ballots, 3840*l.* Bushire, in 1879, exported 2,30,000 *rupees*' worth of raw silk to India. The approximate London market value of Persian raw silk is 9–11*s.* a lb.

Other Countries.—The subject of sericiculture is attracting considerable attention in many other countries, though their production is at present insignificant compared with those just described. In America, the industry is taking a great start, especially in California, Texas, Georgia, Alabama, Connecticut, and Pennsylvania. The Australian colonies possess facilities second to no country in the world for the production of silk, and much may be expected from the efforts that are now being made in this direction. Cyprus formerly produced 70,000–80,000 lb. of silk, which is now reduced to 5000–8000 lb.; the mulberry flourishes everywhere, but the worms have long suffered from disease. Our imports of raw silk from Malta (not of local production) rose from 13,650 lb. in 1876, to 41,713 in 1878, but receded to 26,361 in 1880. The Greek provinces of Calamata and Messina produced 96,250 lb. cocoons, value 12,500*l.*, in 1880; Syra in that year exported 1074*l.* worth to France. Servia before the war of 1876 exported yearly 10,000*l.* worth of eggs and cocoons. Austro-Hungary in 1879 exported 9746 metrical *centners* (of 110¼ lb.) of silk. In the S. provinces of Russia, excellent silk is raised by the German colonists in Ekaterinoslav and Taurida; much is also produced in the Trans-Caucasian provinces. The inhabitants of Turkistan cultivate a considerable amount of silk, much of which finds its way into Russian commerce. Algiers in 1879 exported 15,938 *kilo.* of silk; and French Cochin China, 660 *piculs* (of 133⅓ lb.) in 1880. Uruguay promises to figure soon as a producer.

In England, the failure of numerous experiments has proved that sericiculture cannot be carried on profitably; but, according to no less an authority than B. F. Cobb, the rearing of grain or eggs for the Continental market would be a most remunerative and successful industry.

Imports and Exports.—Our imports of silk knubs or husks and waste in 1880 were:—31,402 cwt., 376,710*l.*, from China; 14,169 cwt., 239,452*l.*, from France; 3086 cwt., 36,738*l.*, from Bengal and Burma; 2577 cwt., 31,054*l.*, from Japan; 1667 cwt., 31,541*l.*, from the United States; 425 cwt., 6369*l.*, from Turkey; 1676 cwt., 28,592*l.*, from other countries; total, 55,002 cwt., 750,456*l.* Of raw silk in the same year:—3,165,935 lb., 2,663,850*l.*, from China; 240,326 lb., 204,202*l.*, from Japan; 81,361 lb., 79,416*l.*, from France; 72,051 lb., 50,336*l.*, from Bombay and Sind; 36,643 lb., 46,160*l.*, from Italy; 32,955 lb., 30,900*l.*, from Bengal and Burma; 26,361 lb., 38,090*l.*, from Malta; 18,317 lb., 17,702*l.*, from other countries; total, 3,673,949 lb., 3,130,656*l.* Our imports of raw silk in 1876 were 6,016,927 lb., value 5,770,341*l.*, since which they have yearly decreased. Our imports of knubs, husks, and waste, on the other hand, show a gradual increase from 29,633 cwt., 406,051*l.*, in 1876. Our re-exports of raw silk in 1880 were 947,165 lb., 741,597*l.*, about 70 per cent. being to France; of knubs, husks, and waste, in the same year, 9241 cwt., 102,809*l.*, over 80 per cent. being to France.

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(See Silk Manufactures.)

SILK MANUFACTURES (Fr., *Soierie, Industrie sétifère*; Ger., *Seidengewerbe*).
According to the most reliable historic records, the Chinese were the first people to utilize the fine, lustrous, and beautiful fibre produced by the various kinds of silkworm (see Silk). The art of silk manufacturing appears to have arrived at considerable perfection 2750 years before the Christian era, as the empresses of China, at that early period, are stated to have busied themselves with their maids in the industry. To one of these empresses, Si-ling-chi, the consort of the Emperor Hoang-ti, is attributed the discovery and invention of a method of reeling the cocoons. The industry continued under the protection and often under the personal superintendence of her successors for many centuries subsequently. The beauty of the fabrics manufactured led in process of time to the growth of an export trade, first with neighbouring nations, and afterwards with those more distant. In this way, silk and silken fabrics penetrated into India, Persia, and the intervening territories, to the borders of Europe. Thence, by the aid of the maritime nations at that time flourishing in the Levant, they were distributed amongst all the ancient peoples who had risen to eminence in civilization at that early day. In the former case, the means by which this was effected were the caravans of merchants who travelled overland from one country to another.

Though the material at an early period thus became known in a manufactured and semi-manufactured form, its origin for centuries longer remained a secret. For a long time, it was conjectured to be a direct production of the vegetable kingdom, and is stated to be such by several ancient authors.

The substantial fabrics of silk that found their way to W. Asia from China were prized not only as valuable products of the loom, but also as affording an excellent source of the raw material, being in many cases unravelled, in order that the threads thus obtained might be rewoven to form the light and semi-transparent articles that excited the censure and ridicule of the moralists and satirists of ancient Greece and Rome.

The story of the introduction into Europe of the silkworm, and the methods of manufacturing silk as practised by the Chinese, by two Nestorian monks during the reign of the Emperor Justinian in 552 A.D., is too well known to need repetition. The emperor, with a keen eye to profit, kept the manufacture a monopoly in his own hands for a considerable time; but it was impossible to maintain such a state of things. Sericiculture and the manufacture rapidly spread over the most suitable territories of the Roman empire, and flourished especially in the Peloponessus. The new industry, though slow in its development, and for 600 years confined mostly to Greece, gradually gained upon that of China, and ultimately sufficed for the supply of the European demand. The Arabs and Saracen princes, who had also become acquainted with the art in both its branches from the Persians, had introduced it into the kingdons of Northern Africa, Sicily, Spain, and Portugal, over all of which they held sway. The Crusades about this period led to considerable political changes, amongst which was the establishment of the Norman power in Sicily. It is to the ambition of Roger, the first Norman king of that country, that the world owes the dispersion of the silk manufacture of Greece, and its introduction into Sicily and Italy. After this king returned from his second crusade in 1146, he invaded Greece, and carried off the treasures of Athens, Thebes, and Corinth, taking captive a large number of weavers and other operatives connected with the silk industry, whom he compelled to settle in Palermo and Calabria, and to teach his people their methods of manufacture. The Crusades also greatly assisted to make silk known in all the countries from which the motley armies of adventurers had been gathered. Those who returned would not fail to convey to willing feminine ears full details of the art of producing the glossy and much prized robes, of which many would only have heard vague reports. The manufacture had not been long established in Italy before it was carried into France.

Sericiculture and the manufacture of the product have always been a favourite pursuit and a cherished industry of the kings and aristocracies of Europe. The rulers of France for more than four centuries made it an object of peculiar care, and by the time of Louis XIV., it had become a flourishing industry, employing in its various branches probably over one million people. Amongst these were the Huguenots, whom the monarch just mentioned banished from their homes. In Lyons, at that date, were over 18,000 looms; and at Tours, over 11,000. These were reduced to about 5000, and even for these, weavers could not be found. The silk industry of France was thus almost annihilated. The result, however, was its establishment in Switzerland, Germany, and England; in the last country, over 100,000 of the refugees found an asylum for themselves and a profitable field for their labour.

Numerous attempts have been made in this country to acclimatize the silkworm, so as to render its cultivation profitable, but without success. Better results, however, attended the efforts to establish the manufacture. From a comparatively early period, it is probable that it was carried on with more or less success, though without becoming in any sense a distinct and recognized national industry. The immigration of the Continental refugees above mentioned, and their settlement in Spitalfields, Norwich, Dublin, and several other places, so increased and concentrated the industry in these localities, that it has been numbered amongst the most important of the textile manufactures of the country ever since.

For a long time, the machinery was rude, and incapable of producing more than "tram," the weft employed in making silken fabrics; whilst "organzine," or warp yarns, had to be imported ready "thrown" from Italy. This, as is well known, was obviated by the introduction of "throwing" machinery from Italy by John Lombe, of Derby, who surreptitiously acquired plans of the machines by engaging as a workman in an Italian mill. The risks he encountered and the obstacles he overcame before he made his establishment at Derby a success are too well known to need detailing here.

The success of the Derby mill soon led to the erection of others at Stockport, Congleton, Macclesfield, Leek, and numerous other places in and around Manchester. For a considerable time, the trade flourished in all these districts, and especially whilst import-duties were levied upon foreign productions, which had a tendency to preserve the home market to them exclusively. But the more profitable industries of cotton and woollen manufacturing, which have undergone such wonderful development, have quite put the silk manufacture into the shade. Owing to the greatly enhanced value of labour in this country, it has become almost impossible to compete against the cheap labour of the Continent without protection. The consequence is that since the repeal of the import duties upon silk manufactures, the trade has been gradually decaying when contrasted with the other textile industries of this country. Whether there is a future before it when its prosperity will revive, and its progress compare with them, is difficult to say.

Raw silk arrives in this country made up into "books," each containing a certain number of knots. That from Italy is twisted up into a thick knot, almost like a short length of rope, about 12 in. long. That from China and Japan is made up into much smaller knots than that of European origin, and a number of these are put together in the form of a brick.

Silk is emitted by the worm from two orifices termed "spinnarettes" in the form of two fine filaments, which the worm unites into one thread, of which it forms its cocoon. In winding the cocoons, five or six of these double threads are wound together, and slightly twisted to form a thread capable of being manufactured. Owing to the softened state of the natural gum of the silk caused by steeping the cocoons in warm water, as they are reeled and twisted, they readily unite into one thread. In this form, the silk is purchased by the "throwster" or spinner, provided he does not reel from the cocoon.

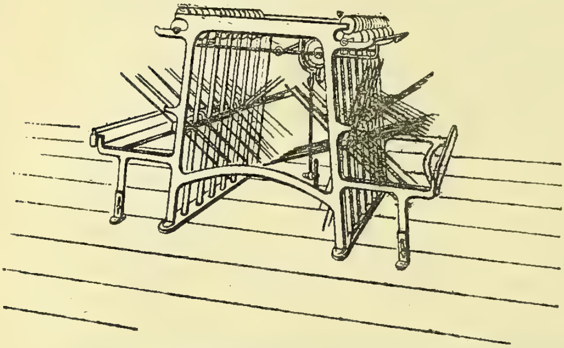
Raw silk in the processes of manufacture becomes either "organzine" or "tram," according to its treatment. The former is used for warp purposes, and generally consists of two "singles" twisted or "thrown" together. For fine warps, single alone is used. The weft yarns are composed of two or more singles, slightly twisted, in order to admit of the better distribution of the fibres over the warp threads, which they are usually intended to cover in the most perfect manner.

The processes through which it is necessary to put the raw material as imported into this country, in order to prepare it for organzine for weaving, are the following:—(1) Winding, (2) cleaning, (3) spinning, (4) doubling, (5) spinning, (6) reeling. The first operation of spinning, being of the "single," puts in about 15 turns to the inch of thread; the second, which combines two or more threads, imparts about 8 turns an inch. When tram is being prepared, the operations are nearly the same, omitting the first process of spinning, and reducing the turns to four or less in the second or throwing, to obtain the looseness of structure that will yield the desired end.

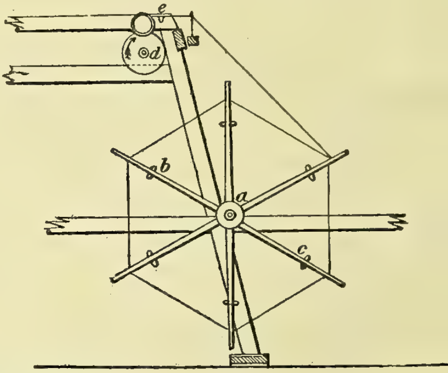
The first step taken with raw silk is to separate the "book" or "moss" into knots, and sort these into lots according to their respective fineness, as well as can be judged by the eye. This separation is, however, a very imperfect one, as the unaided eye is scarcely equal to discriminating between the differences in the thickness of the threads; and in addition, there are many knots that contain both fine and coarse thread, changing to one or the other in the space of a few yards. After this preliminary, the hanks are dipped for a short time in a solution of soap and water, to soften the gum upon the fibre, which renders it more pliable and easy to wind, for which operation it is then ready.

Winding.—The winding-machine, Fig. 1226, is generally arranged in the swifts to take either Italian, Chinese, or Japanese reeled silks. It is a very simple machine, consisting of little more than the framework, the swifts, and a roller carrying friction-drums, on which the bobbins for the reception of the silk revolve. These, being duplicated, render the machine double. Fig. 1227 shows a section of the working parts. The swift *a* is composed of a hub or nave of wood, into which are inserted six pairs of thin lancewood rods *b*. Each pair of rods is connected near the top by thin cords; to keep the latter at proper tension, a wedge *c* is put below the cords, and presses the lancewood rods apart. Both cords and rods can be easily adjusted to receive any size of hank. Each swift has a small weight suspended upon the hub, in order to prevent its too rapid revolution, and to impart the requisite tension to the thread in process of winding. The bobbins are fixed upon spindles having heads or small rollers, and are actuated by friction-wheels *d*. A slot *e* is prepared for the spindle when out of contact with the friction-driver. Fig. 1228 exhibits another form of winding-machine.

1226.

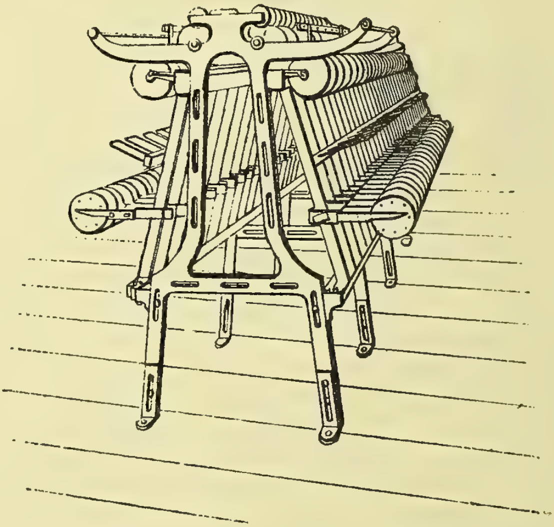


1227.



A "slip" or hank having been put upon the swift, the end of the thread is found, and the winder, wetting it in her mouth, casts it upon the bobbin, to which it adheres; this being placed upon the driver, the winding commences, the thread having been previously inserted into the curl or ring of the guide-wire, fitted into the traverse-rail, whose lateral movement winds the thread regularly upon the bobbin. When the hank is wound off, or the thread breaks, the end is joined to that upon the bobbin by a peculiar knot formed to prevent slipping in subsequent operations. The guide-rail or traverse-bar is operated by elliptical wheels, or heart-shaped cams, in order to make a bobbin of a good form. To prevent waste of material and loss of time, the winding is arranged so that each successive layer shall obliquely cross the threads of the preceding one. Winding-frames generally contain 30–40 swifts to each side of the machine.

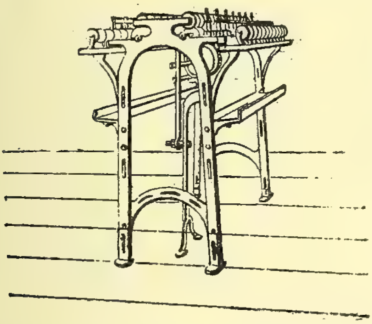
1228.



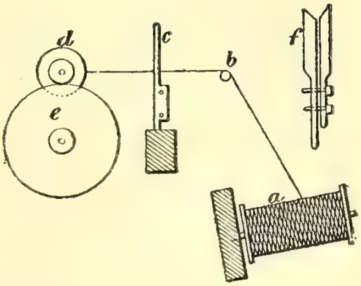
Cleaning. — The cleaning-machine, Fig. 1229, which is often called the redrawing frame, to which the bobbins from the winding-frame are now conveyed, is of similar construction to the preceding machine. For the swifts of the winding-frame, is substituted a bobbin-board, fitted with pegs to hold the bobbins; whilst in place of the guide-wires of the traverse-rail, the thread passes between two vertical steel blades, whose edges are set so closely together as to detect and arrest any knots, slubs, or other defects of a gross kind that would interfere with the perfection of the subsequent stages of the work. The distance between the edges of these blades can be adjusted with great nicety by means of screws. Fig. 1230 shows the working parts in section. The bobbin *a* from the winding-machine is placed upon the pin in the board, so as to allow of easy revolution in unwinding. The thread is conducted over the carrier-rod *b*, next passing through the cleaner or vertical blades *c*, and thence upon the bobbin *d*, actuated as before by the friction-wheel *e*. The cleaner is fixed in the traverse-bar or guide-rail. An enlarged front view of the cleaner is shown at *f*.

Cleaning is not the only purpose of this process; an object of equally great importance is the "sizing" of the silk, a word implying a very different process from that which the same term indicates when used in connection with the cotton trade. It means the still further elimination of the irregularities of raw silk, enabling the manufacturer to produce an even fabric. As the winding proceeds, the attendant is carefully observing the threads, and when one of these begins to deliver a thread finer than required, it is broken off, and the bobbin is moved to the right; if a coarse thread comes off, it is similarly moved to the left. When the process is completed, the silk is thus assorted into two sizes, which are marked firsts and seconds. When it is desired to secure the most perfectly even threads, this process is repeated several times, though all of them constitute but a very imperfect remedy for careless reeling from the cocoon.

1229.



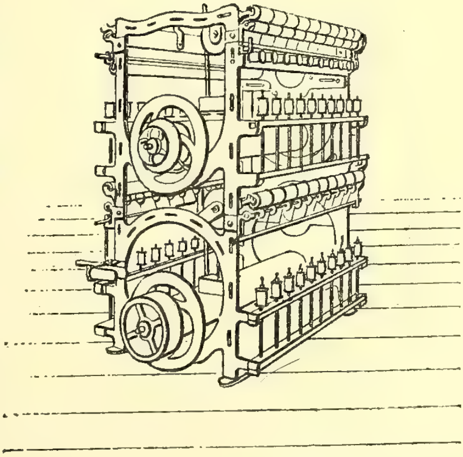
1230.



In this form, the silk is technically called "dumb singles," because, being in the gum, it does not show up its lustre. Though it has no twist, it is sufficiently strong for the warp purposes of particular fabrics, such as gauzes, bandanas, &c.; it is sometimes used for weft purposes also. In both cases, it must be used in the natural gum, as if it were attempted to clear it or dye it, to bring up the lustre or improve the colour, it would be rendered too soft and flossy for use. The silk is therefore cleared in these cases in the fabric, being boiled or dyed after manufacture. It is, however, sometimes "stained" by immersion in a cold dye-bath, when it is necessary to get a coloured thread; but in this case, the colour is neither so fast nor so lustrous as when treated in the other manner.

Spinning and Doubling.—After the cleaning and the sizing process of the last stage, the thread is ready for the spinning-machine, to which the bobbins are conveyed.

1231.

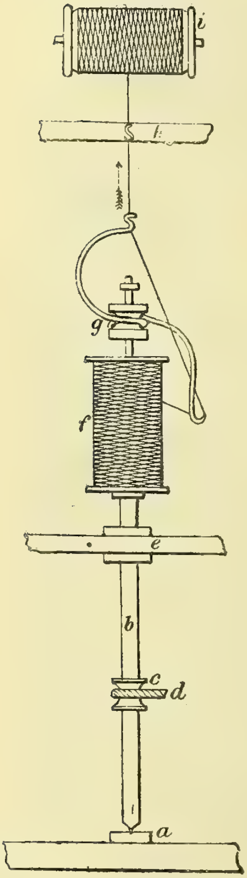


Assuming that organzine is required, the process is to spin or twist the "single" thread, composed of the filaments reeled together from the cocoon. In this case, it is customary to put about 15 turns an inch for most descriptions of work, though, in many instances, this number is departed from, according to special requirement. In some cases, when singles are intended for organzine, 60 turns an inch are put in.

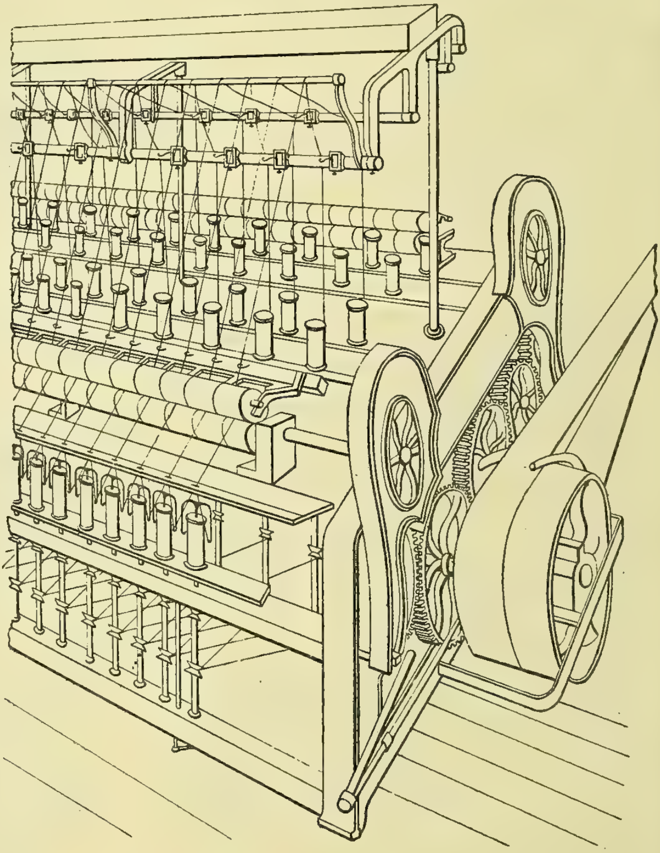
The spinning-machine, Fig. 1231, usually contains two tiers of spindles, one above the other, the whole amounting to several hundred. The driving-shafts, one for each tier, carry a cylindrical tin drum extending the length of the frame. This drum actuates the spindles by means of driving-bands, one for each spindle, which pass around it, and thence around the wharve upon the lower part of the spindle between the bolster and the footstep. Fig. 1232 shows the details of one of these spindles and its mountings: *a* is the footstep in which the spindle *b* revolves, carrying the wharve *c* for the reception of the driving-band *d*. Midway in its height, the spindle passes through a bolster-rail *e*, fitted with brass bearings, in which it revolves. Just above the bearing, the spindle is tapered for the reception of the bobbin, the smallest diameter being at the top. The bobbin *f* from the cleaning-machine, being adjusted upon the spindle, is firmly held upon the tapered part, and above it is mounted the flier *g*, composed of a small wooden boss, having a groove around its circumference, into which the wire forming the flier-arms is bent and secured. The extremities of this wire are curved to form eyelets for the reception of the thread. The traverse or guide-rail *h* is also fitted with eyelets.

In the process of spinning, the thread, both single and double, is conducted from the bobbin *f* through the lowest eyelet of the flier, around the limb *h*, through the upper eyelet, as well as that of the traverse-rail, and thence upon the bobbin *i*, whereon it is wound in crossed layers, as before, and for the same purpose. It will be observed that the course of the thread in silk-spinning is the reverse of that in other textile fabrics, being delivered instead of received by the bobbin upon the twisting-spindle. Should the thread be drawn from the bobbin *f* with the spindle at rest, one turn or twist would be imparted to it for every revolution drawn off. Suppose, however, the spindle to be making 6000 rev. a minute, and the draft of the bobbin to be 400 in. in the same time, it is obvious that this will give 15 turns for 1 in. of the thread, plus one turn for every rev. of the thread drawn from the bobbin required to yield 400 in. When single is being spun for organzine, and more twist is required, the draft of the bobbin *i* is diminished in proportion.

1232.



1233.



In silk-spinning, the flier is sometimes dispensed with, its chief use being to protect the thread from injury by friction during delivery from the bobbin, which some think is a more imaginary than real risk. As will be seen from the description of the machinery already given, and the nature of the silk filament or cocoon thread, the working of silk, especially in the throwing department, is exceedingly simple, consisting only of winding and twisting, and hardly affording much scope for the ingenuity of the mechanical inventor. Hence it is that improvements are comparatively rare and unimportant.

A machine, however, has recently been introduced for spinning or twisting purposes which is a considerable improvement upon preceding ones, owing to its productive capacity per spindle being double that of most others, thereby enabling considerable economy to be effected in space, waste, shafting, gearing, belts, buildings, and labour.

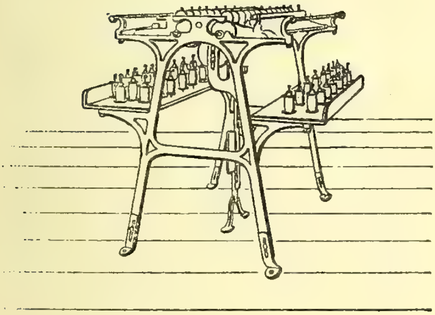
The structure of this machine, Fig. 1233, which can be adapted to any fibre, more nearly approximates to that of the bobbin-and-fly-frames, as used in cotton industry, than to machines employed in the silk manufacture. Instead of the bobbins containing the material to be treated, reposing in a bank or creel on pegs, as usual, the machine is fitted with a creel or set of spindles which carry the bobbins containing the threads to be twisted, and these spindles are made to revolve at a great speed. Thus, running at the same rate as the front or twisting-spindles, which may be assumed to be 4000 rev. a minute, half the twist is put in before the yarn reaches the draft-rollers, when it becomes subject to the action of the front spindles. These working at the usual speed, and having only half the task to perform, it enables the rollers to be put on double speed, thus filling the bobbins in half the time, and ensuring a double production.

The ordinary spindle carries an extra wharve, from which, power is transmitted by means of a band to the creel spindle, mounted in rails. On the top of this spindle, is placed the bobbin containing the threads to be twisted. Being fixed on the spindle, the bobbin revolves with the spindle, which puts in half the required twist before the thread reaches the rollers. As this result is accomplished without any increase of the speed of the spindle, the advantages of the process will be obvious. It enables the production of every spindle to be doubled, whilst cost in wages is not increased. Only half the space is required, as compared with the ordinary method, the shafting, gearing, complementary fittings, cost of supervision, and all other expenses, being obviated.

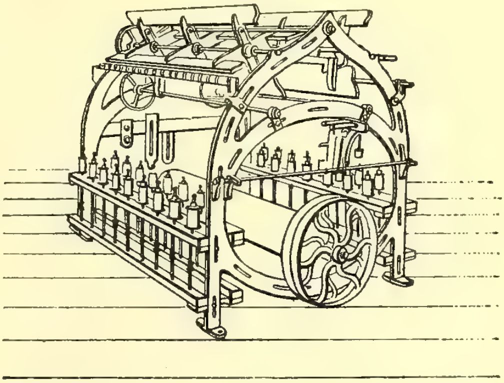
This machine is known as "Murray's patent," and is made solely by Thomas Unsworth, of Manchester. When it is used, the bobbins are prepared for it preferably upon the winding-doubling-machine of the same maker, described in the article on Rope (see p. 1595). The single having thus received the twist necessary for forming organzine, in which two strands of the single are combined, it is taken to the doubling-machine, Fig. 1234, in which two threads or more if required are wound upon one bobbin in a manner as perfectly parallel as possible, in order that all may be of exactly the same length, which, in the subsequent operation of twisting, is requisite to produce organzine of the best quality. It differs so little from the machines previously described, that it calls for no further notice.

Having been doubled, the threads are again brought to the spinning-frame, and, for organzine, are twisted about 8 times an inch, but in a direction opposite to that of the first twist. When tram is required, this is the only twisting or spinning to which the thread is subjected, and in this it only receives about 4 turns an inch, the result being that a soft spongy thread is formed, well adapted to cover the warp threads, and show up the lustre of the fibre.

1234.



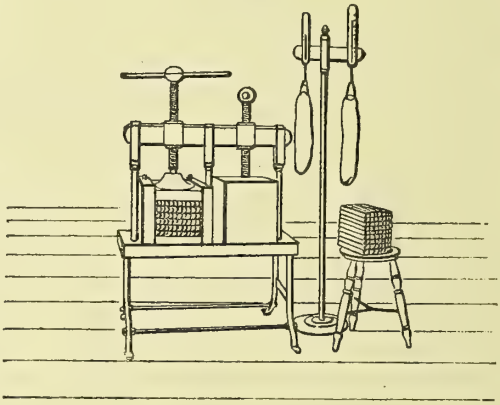
1235.



Reeling.—Reeling is the next and last operation so far as the throwster's portion of the business is concerned, except the packing for the market. The reeling-machine, Fig. 1235, is simply a hank-winding machine, in which the silk, as it finally leaves the spinning-frame, is wound into a form to fit it for the operations of boiling, to clear it from the natural gum, and dyeing, in which the richest colours are imparted to it previously to its being woven or otherwise fabricated into the numerous articles of luxury for which from the first it has been designed. This machine, like all the others illustrating this article thus far, with the exception of Fig. 1233, is made by Enoch Rushton, Macclesfield, and is fitted with his self-acting count-guider ~~and~~ stop-motions. The former registers in yards the exact length of each skein; when the length required has been reeled, the guider makes a lateral movement, and alongside the first skein runs another the same length, and so on in succession until the reel is full, when it stops the machine. By this means, perfect uniformity in the length of skein or hank is secured. These skeins, being afterwards carefully weighed on dramming- or deniering-machines, being all of one length, can be "sized" or assorted with great correctness.

After silk is thrown, it is generally reeled into skeins of 1000 yd., and to ensure regularity, these are assorted as just described, and arranged in lots, ¼ dram difference in weight defining the lots. Thus, if 1 skein weighs ¼ oz. = 4 dr., it is denominated 4-dram silk; if ¼ dr. lighter, it is 3¾-dram silk, &c. Where the greatest regularity is desired, and the expense is not an obstacle, silk is reeled into half-skeins of 500 yd., or quarter-skeins of 250 yd., and then carefully weighed and assorted as before. This process is called "half-" and "quarter-sizing." In France, the skein measures 520 yd., and is weighed in *deniers*, the *denier* being equal to 0·825 gr.

1236.



When the process of assorting or sizing has been completed, the silk is gathered into hanks, twisted into knots, arranged in bundles, and pressed in the manner shown in Fig. 1236.

Silk, besides being thrown into the form of organzine and tram for weaving, is made to assume numerous other special forms and designations, according to requirement. Amongst these, may be mentioned embroidery-, fringing-, sewing-, knitting-, and machine-silks. There is, however, no essential difference in them, all being simply combinations of the number of threads needed to give the thickness, and of variations in the twist required to obtain the effect.

Silk at this stage becomes a mercantile article, known as "thrown silk," and as such is sold to manufacturers, who weave or otherwise work it into the forms in which it is presented to the consumer. In many instances, the processes of throwing and manufacturing are combined in one establishment.

The silk thus usually comes into the hands of the manufacturer in the form of "hard" silk, as it is technically called, when in the gum previous to boiling. Before dyeing, it always undergoes this operation, which greatly changes its appearance. In the gum or natural state, it is dull, hard, and wiry, and might easily be mistaken for several other fibres. Boiling reduces its weight nearly one-third, softens it, and develops its lustre, bringing out its wonderful brilliance. It then becomes "soft silk." It is manufactured in both these states, though comparatively rarely in the former.

In dyeing, the weight of the dye-stuffs partially restores the loss caused by the removal of the gum; but advantage is very often taken of this process to load the material heavily with chemicals, sometimes to the extent of 5–6 times the original weight. In some cases, as for instance when the silk has to be manufactured into fringes, and is required to hang heavily, this weighting is advantageous in obtaining the effect; but as a general rule, all weighting may safely be regarded as adulteration, and intended to cheapen the cost of production. It is certain that the chemicals used to weight it injure its strength and durability, and, in the end, enhance the cost.

Spun Silk.—In silk growing and the subsequent manipulation of the material in transforming it into articles of utility, it will be obvious that a considerable quantity of waste material must accumulate. The floss-silk, or outer covering of the cocoon; the perfect cocoons reserved for propagation, and which are pierced by the insect; badly formed, entangled and otherwise defective ones; the bottoms of cocoons when the usable filament has been wound off; and the loose fibre produced in after stages of working, all contribute to the stock of waste. The aggregate weight of material obtained in this manner forms a large percentage of the entire weight of the crop of cocoons. When it is considered that all silk-producing countries are sources of supply, it will be seen that the bulk of fibre of this description placed at the disposal of manufacturers is very great.

Until about 1857, this waste was the most useless bye-product obtained from any of the textile industries. The world is indebted for its utilization to Samuel Cunliffe Lister, of Manningham, near Bradford, by whose mechanical genius and enterprise it was made to serve a useful purpose.

The manufacture of silk-waste differs radically from that of net or thrown silk, being much more akin to the manufacture of worsted. The different varieties of silk, such as Italian, Chinese, Japanese, and Bengal, are kept apart, owing to their varying qualities. But the waste from all may be worked together, though it is usual to separate them according to shades of colour. The classification is generally into two shades, yellow and white; the former is termed Italian, and the latter Chinese. Sometimes the yellow tint of the first-named sort is removed or covered by a process of dyeing, which imparts to it the whiteness of the latter. Should the material thus sophisticated be boiled at a subsequent stage, the original tint will reappear, and may cause defects in the fabric into which it has to enter. It is therefore important for the manufacturer to know when it has been subjected to such treatment.

On the Continent, it is customary for spinners to work waste silk with the gum in it, in which state it is known as "Schappe silk." English manufacturers, however, usually prefer to clear the gum from it by boiling. This is the first process to which it is submitted. After boiling, the mass presents a rich lustrous appearance, but thoroughly entangled.

It is now ready for the "breaker," a machine allied in its function and structure to the "rag-devil" of the shoddy manufacture (see Woollen Manufactures), which tears, breaks, and disentangles the fibrous mass. The latter is by this means reduced to lengths from 12 in. downwards, by which it is fitted for the process of combing.

The principle of combing is similar to that employed in the manipulation of long wool for the production of worsted, with the modifications rendered necessary by the different nature of the material. In combing silk-waste, the material is separated into several portions, each of a different length of staple, and the combing-machine is consequently arranged to obtain this result. The first draft yields a staple about 12 in. long, which can be spun into 100's–140's single thread; this is called "first drafts." The next in length is called "second drafts," and is suitable for the production of 70's–90's. There are several successive ones, named thirds, fourths, fifths, &c., which are utilized in the production of coarser yarns. The short fibre remaining after the abstraction of the preceding lengths of staple, and which is too short to comb, is called "silk-noil," and is relegated to the silk carding-machine, which differs very little from those for cotton or wool. It is subsequently treated in the same manner as those fibres, the product being finally known as "carded spun silk," or "short spun silk," to distinguish it from combed silk-yarn, which is called "long-spun" or "patent silk." The perfection to which the combing process has been carried leaves very little material available for carding purposes, and the yarn produced from the latter is disappearing; it is going out of favour also from another cause, namely, its lack of lustre as compared with that produced from the combing process.

The different lengths of silk "top" produced from the raw material by the comb are further drawn and combed to form a "sliver," a number of these being combined and drawn into one, to eliminate irregularities and secure perfect uniformity. This process is repeated several times according to requirement, and the quality of yarn it may be desired to obtain. The sliver is next passed through a roving-frame, in which it is attenuated to the required degree, and wound upon a bobbin for the supply of the next machine, the spinning-frame, constructed on the principle of the cotton throstle-machine. The short-spun or carded silk is spun upon the mule (see Cotton Manufactures, pp. 753–60).

Yarns spun from silk-waste are not so perfect as those obtained from other fibres. The combing and carding processes are insufficient to thoroughly cleanse the material from impurities, lumps and rough bits remaining on the thread to a large extent. A simple and ingenious process has been invented, called "improving," by which the thread is very much cleared and improved in appearance. When the bobbins have left the spinning-machine, they are taken to another machine, and the thread is run from one bobbin to another, passing around several revolving spindles fixed on the cleaning-bar, and arranged so that the travelling thread rubs against itself, the friction clearing away the lumps and roughnesses not imbedded in the thread. The yarn is remarkably improved by this operation. When it is required of particular count, and has to be submitted to this process, it must be spun considerably heavier, as the weight is much diminished by the friction and loss resulting.

Still another process remains. Spun silk can never be made to equal thrown silk in its lustre, but it is greatly improved by the "gasing," in which operation the thread is run rapidly through a jet of gas, which burns off the extremities of the fibres that project from the surface of the thread. When these are cleared away, the light has direct access to, and is reflected from, the surfaces of the long fibres laid parallel in the thread, by which its lustre is greatly increased.

For purposes in which the strength of silk only is required, both the above processes are omitted, as, owing to the reduction of the weight consequent thereon, and the cost of labour, the price is enhanced fully 2*s*. a lb. Where, however, a lustre approximating to that of net silk is required, the yarn is always submitted to both of them.

Spun silk is more lustrous than perhaps any vegetable or animal fibre with which it comes into competition, with the exception of thrown silk, and being capable of yielding uniformly level and round yarns, which cannot be obtained from thrown silk, it possesses advantages for some purposes even over the latter. Owing to this quality, a good sightly fabric can be produced in the power-loom, free from the "stripey" character often seen in thrown-silk goods, even when made in the hand-loom, and which defect originates in the irregular thickness of thrown-silk threads. Combed spun, or patent silk, has come into general use for sewing-machine purposes, having of late years quite superseded thrown silk in that sphere. It has also been adapted for use in the manufacture of many other articles, amongst which may be mentioned cords, braids, fringes, tassels, heavy laces, and numerous smallwares; fabrics such as "cut-ups" for tie and scarf purposes, dress goods, handkerchiefs, mufflers, &c., and in these and other capacities fills a very useful place amongst textile fabrics.

Weaving.—The weaving branch of the silk manufacture as an art has been carried to the highest degree of perfection yet attained in any of the textile industries. The fineness, strength, lustre, and affinity for dyes, of the raw material, are qualities that cause it to lend itself with great facility to the purposes of the designer, and the requirements of the weaver. The rich lustre of a black cachemire, contrasts finely with the dense black of a velvet fabric, and the latter again with the sheen of a satin. Figured damasks, produced by the jacquard attachment, show another phase of the excellent results attained in the manipulation of this premier textile fibre, whilst the brilliant hues that can be obtained when the resources of tinctorial art are called in to aid, demonstrate that practically when wealth is at command there is no limit to its use for decorative purposes. To show what can be produced, portraits, pictures, landscapes, and artistic effects have been wrought of such perfection and beauty as to vie with the products of the pencil or the graver. These highest results are mainly the outcome of the handicraft form of the industry, as, owing to facts previously explained, the material does not surrender itself easily to the requirements of automatic mechanism. With the development of invention and increasing skill, some of the difficulties yet encountered will no doubt in the early future be obviated; but even without improvement in that respect, accomplished results are so excellent that only the relatively high price of silk articles precludes a great extension of consumption. Growing wealth on the one hand, and extended sericiculture on the other, will do much to remove this obstacle. By many persons highly qualified to form correct opinions on the matter, this view of the future is regarded as very likely to be realized.

Statistics.—The manufacture of silk in this country during the past twenty years has continuously diminished. The causes which have led to this are not far to seek. The extraordinary development of other industries greatly drained the labour supply formerly available, enhancing the value of that which remained; legislative enactments in the interests of the operatives further hampered the trade when brought into competition with the unrestricted, unprotected, and cheap labour of the Continental states; and the final blow was the sudden abolition of the import duties on foreign silk goods on the conclusion of the first treaty of commerce between France and this country. From the check then received, the silk industry of this country has never recovered, and a steady diminution of its extent and importance has since taken place.

The following table exhibits a summary of its condition in 1879 as shown by a Return to Parliament. A comparison is also afforded with its state in 1874.

	No. of Factories.	No. of Throwing Spindles.	No. of Doubling Spindles.	No. of Power Looms.	No. of Power-loom Weavers.	No. of Persons employed.		
						Males.	Females.	Total.
England and Wales ..	700	832,748	166,289	12,335	—	11,702	28,514	40,216
Scotland	5	9,790	10,112	211	—	69	548	617
Ireland	1	—	—	—	—	102	50	152
Total in .. 1879	706	842,538	176,401	12,546	No return.	11,873	29,112	40,985
Total in .. 1874	818	1,114,703	221,708	10,002	6,080	13,171	32,388	45,559

The figures of these returns give the numbers of workers subject to the enactments of the Factory Acts. Much of the silk industry has, however, remained a domestic occupation, for which it is peculiarly suitable. Those employed in this section do not therefore fall within the enumeration. They form fully one half: if the particulars for the above periods be each multiplied by two, an approximately accurate result will be obtained.

Our imports of silk manufactures from countries out of Europe were valued at 330,744*l.* in 1879, and at 239,852*l.* in 1880; and from countries in Europe, at 12,511,174*l.* in 1879, and 13,085,083*l.* in 1880.

Our exports of silk manufactures in the year 1880 were as follows. Broad-stuffs of silk or satin, 3,746,830 yd., 710,365*l.*, nearly half being to France, and almost a quarter to Australia. All-silk handkerchiefs, scarfs, and shawls, 409,189*l.*, about three-fourths being to Bengal and Burma. Silk ribbons, 123,429*l.*, more than half to Australia. Silk lace, 109,953*l.* Unenumerated all-silk goods, 250,807*l.* Broad-stuffs of silk and other materials, 2,471,680 yd., 302,355*l.* Other kinds of goods containing silk, 124,561*l.* Grand total value, 2,030,659*l.* R. M.

(See Cotton Manufactures; Silk; Woollen Manufactures.)

SKINS (Fr., *Peaux*; Ger., *Häute*).

Skins whose industrial value depends upon the attached hair or feathers, rather than upon the corium itself, have been described under Feathers (pp. 904–9) and Fur (pp. 1029–33); there remain for description in the present article those skins and hides (the latter term being commercially applied to the skins of the larger mammals) which are valued for themselves. As the structure and morphology of hide have been treated of at length in Leather (pp. 1213–40), the present article will be concerned chiefly with the trade in skins, which possesses no small importance. Many of the statistics relating to skins are collective, and not specific; these will be grouped under the heads of the respective countries, after all accessible details have been given upon each kind of skin.

Alligator.—In the S. United States, notably Florida, the supply of alligator-skins amounts to many thousands annually, and the "farming" of the reptiles for their skins is even spoken of. The principal market for them is Europe, but no statistics of the trade are published.

Armadillo.—The skins of this animal were exported from Brunei (Borneo) to Singapore to the value of 121 *dol.* (of 4*s.* 2*d.*) in 1879.

Ass.—Hankow exported 2402½ *piculs* in (of 133⅓ lb.) of asses' skins in 1878, and 1068 *piculs* in 1879.

Buffalo.—Manilla (Philippines), in 1878, exported 379 tons of buffalo-skins, value 12,130*l.*, and 274 tons of cuttings, 6579*l.* Hankow exported 1091 *piculs* in 1878, and 1238 in 1879. Brunei (Borneo) sent 1362 *dol.* (of 4*s.* 2*d.*) worth to Singapore in 1879. The approximate London market values of buffalo-skins are:—Batavia, 4–7*d.* a lb.; Bengal, 3–6*d.*; other sorts, 2½–6½*d.*

Calf.—Hamburg exported to Great Britain of calf and other skins in 1876, 20,731 cwt.; in 1877, 27,550; in 1878, 14,583; and in 1879, 19,287 cwt. The Hawaiian Islands sent 168 pieces to Germany in 1879. Christiania shipped 31,000 *kroner* (of 1*s.* 1½*d.*) worth to Great Britain in 1878, and 300 *kr.* in 1879. The exports from Archangel (including seal) in 1878 were 335 pieces to Holland, and 23,108 to Germany, total value 2343*l.* Honolulu, in 1878, exported 651 pieces, being 500 to Germany, 135 to China, and 16 to the United States. Memel, in 1879, sent landwise over the Russian frontier for German markets, 34,400 pieces, value 5450*l.* The approximate London market value of calf-skins is 15–34*d.* a lb.

Deer.—San José (Costa Rica) exported 21,121 lb. in 1878. Kiungchow (China) exported 17,544 pieces, value 541*l.*, in 1879. Ciudad Bolivar (Venezuela), in 1879, sent 77,305 pieces (168,176½ lb.) to New York, and 14,695 pieces to Germany. Guatemala, in 1879, exported 2353 pieces to Germany, 693 to New York, and 100 to Belize. Panama shipped 765*l.* worth of deer and other skins to the United States in 1879. Costa Rica exported 82,168 lb. in the year ended April 30, 1879. Puerto Cabello (Venezuela), in 1879, shipped 2466 *kilo.* (of 2·2 lb.) to Great Britain, 11,619 to Germany, 6182 to the United States, and 1281 to Holland. The Commercial Society of Mozambique sold 41 deer, 391 buck, 2168 blesbok, and 3071 other antelope skins at Rotterdam in June 1876. The approximate London market values of deer skins are: Blesbok, Cape, 6–17*d.* a lb.; Deer, E. Indian, 22–50*s.* a doz.

Dugong and Manatee.—The skins of these animals, more important perhaps as oil-yielders (see p. 1365), are smooth, bluish-black in colour, and nearly 1 in. thick. They are well adapted for machine-belting. About 50 are shipped annually from Queensland.

Fish.—The skins of many true fish are strong, firm, and durable, and capable of wide industrial application. Flat-fish give a skin suitable for gloves and fine upper leather. Sole-skins will make purses. Thornback-skins may replace sandpaper for cabinet-making purposes. Eel-skins will make strong braces. Siluroid skins are largely converted into gloves at Colborn, in Canada. Torsk-skins have been made into shoes. Some Red Sea fish-skins are utilized for sandal-making in Egypt. Burbot-skins form durable bags used by some Tartar tribes. Salmon-skins make a leather as tough as wash-leather, and about the thickness of dog-skin, the scale-marks giving a neat pattern; they are employed in clothing by some of the peoples of E. Asia. The skins of the sea-angel, thorny shark, tiger shark, and some skates are used for burnishing, and for covering boxes. Ray-skins are converted into shagreen; France imported 18,000 lb. of them in 1863, chiefly from Portugal. The blue dog-fish gives a skin which is widely used for polishing.

Goat and Kid.—Our imports of undressed goat-skins in 1880 were:—937,691, 113,051*l.*, from British S. Africa; 345,217, 41,155*l.*, Bengal and Burma; 302,590, 23,827*l.*, Turkey; 220,206, 22,861*l.*, Madras; 205,122, 24,595*l.*, Belgium; 77,151, 11,747*l.*, France; 74,464, 9969*l.*, Germany; 61,882, 5368*l.*, Egypt; 31,895, 2989*l.*, Bombay and Sind; 284,842, 36,418*l.*, other countries; total, 2,541,060, 291,980*l.* And of undressed in the same year, from:—Madras, 5,829,608, 626,232*l.*; Bombay and Sind, 1,369,137, 123,633*l.*; Bengal and Burma, 796,214, 90,252*l.*; France, 356,153, 72,335*l.*; Aden, 215,992, 20,424*l.*; Turkey, 113,039, 14,863*l.*; Holland, 107,588, 19,324*l.*; other countries, 138,444, 18,699*l.*; total, 8,926,175, 985,762*l.* The total number is 11,467,235, as against 8,051,112 in 1876. Our imports from British India rose from 55,929 undressed in 1876 to 597,318 in 1880; and of dressed, from 6,127,900 in 1877 to 7,994,959 in 1880. Ciudad Bolivar (Venezuela) sent 317 pieces (284 lb.) to New York in 1879. Tripoli exported 7000*l.* worth in 1879, and 3000*l.* in 1880. In 1880, a number of raw goat-skins were sent from the Marche and Romagna to the United States, weighing about 1½ *kilo.* (of 2·2 lb.) each, and to be used chiefly for ladies' shoes and pocket-books. Shanghai, in 1878, exported 164,285 pieces. Tangier, in 1879, sent 12 cwt., 60*l.*, to Great Britain; 3637 cwt., 18,185*l.*, to France and Algiers; 10 cwt., 50*l.*, to Spain; total, 14,636 doz., 18,295*l.*; and 3046 cwt., 13,707*l.*, in 1880. The Hawaiian Islands, in 1879, shipped 24,940 pieces to the United States (Pacific ports). In 1879, Christiania exported 65,700 *kroner* (of 1*s.* 1½*d.*) worth of goat and sheep skins to Great Britain. The shipments of goat and kid skins from the French E. Indies to Great Britain fell from 5500 in 1876, to 4894 in 1877, and 300 in 1879, with none since. The shipments from the Cape to Great Britain were 794,637 in 1878, 657,509 in 1879, and 934,810 in 1880. Cadiz, in 1877, sent 404 *kilo.* (of 2·2 lb.) of kid skins, value 84*l.*, to Great Britain, and 3866 *kilo.*, 805*l.*, to France. Puerto Cabello (Venezuela), in 1879, despatched 28,684 *kilo.* to Germany, 124,964 to the United States, 14,295 to France, and 18,536 to Holland. Honolulu sent 64,525 pieces to the United States in 1878. Samsoun (Turkey) exported 130,700 *kilo.*, 6796*l.*, to France in 1878. The Cape exports fell from 1,478,761 pieces in 1874, to 687,570 in 1879. Memel sent by sea 7 cwt., 73*l.*, in 1879. Tientsin (China) exported 38,107 *piculs* (of 133⅓ lb.) in 1879. Mogador (Morocco) forwarded 112,974 doz., 59,243*l.*, to Marseilles in 1878, and 8407 bales, 48,000*l.*, in 1880; these skins are used for the manufacture of morocco leather, for which they are peculiarly suitable, owing to their fineness of grain, caused, it is said, by the rich diet, consisting of the fruits of the argan tree (see Oils, pp. 1377–8). The approximate London market values of goat-skins are:—E. Indian, 4–15*d.* a lb.; best tanned, 2*s.* 4*d.*–3*s.* 8*d.*; inferior to good tanned, 9*d.*–2*s.* 5*d.*; Cape, best, 11–18*d.*; Cape, inferior to good, 8–14*d.*

Horse.—Shanghai exported 458½ *piculs* in 1878. Rio Grande do Sul exported 10,714 pieces salted, and 601 dried, in 1879. The approximate London market values of horse-hides are:—English, 9–14*d.* a lb.; River Plate, 6–21*s.* a hide.

Kangaroo.—The skins of this animal are largely exported from Australia and Tasmania, forming some of the most pliable leather known.

Lamb.—The exports from Asterabad (Persia) viâ Gez in 1879 were 788 bales Bokharan, 60,613*l.* Calamata and Messenia (Greece) produced in 1880, 137,500 lb., 2680*l.* Dedeagatch (Turkey), in 1878, exported 500 bales of lamb and kid skins, value 4000*l.* The exports from Ancona (Italy), including kid and rabbit, in 1878, were 609,826 *kilo.* (of 2·2 lb.) to Italy, 41,480 to Austria, 2714 to Germany, 2655 to Greece, 19,486 to England, 3180 to Turkey; total, 679 tons, 50,321*l.* Tientsin (China), in 1879, shipped 35,008 *piculs* (of 133⅓ lb.).

Llama.—The skin of the llama is growing in importance in Parisian shoemaking. It weighs on an average 6 lb., and contains 18 sq. ft. of leather, costing about 1*l.* The source of supply is the Peruvian Andes.

Ox and Cow.—Coquimbo (Chili) exported 4709 ox-hides in 1879. Santos (Brazil) in the year ending Sep. 30, 1879, exported 316,940 *kilo.* salted, valued 5800*l.*, and 1282 dried, 25*l.* The shipments from Christiania to Great Britain fell from 47,500 *kroner* (of 1*s.* 1½*d.*) worth in 1877, to 3500 *kr.* in 1879. San José (Costa Rica) despatched 449,870 lb. in 1878. The exports from the Cape, including cow, fell from 150,875 pieces in 1878, to 104,281 in 1879. Rio Grande do Sul, in 1879, shipped 455,315 pieces salted, and 499,960 dried. Of cow-hides, Hankow exported 35,265 *piculs* (of 133⅓ lb.) in 1878, and 21,063 in 1879. The Kiungchow exports (including buffalo) in 1879 were 490 *piculs*, 818*l.* From Shanghai (including buffalo) went 26,070 *piculs* in 1879. Chinkiang fell from 7262 *piculs* in 1877, to 3974 in 1878, and none in 1879. Memel, in 1879, sent away by sea, 75 cwt., 136*l.*; and over the Russian frontier for German markets, 3000 pieces, 3000*l.* The approximate London market values of ox and cow hides are:—Buenos Ayres and Monte Video, 1st dry, 9–10½*d.* a lb.; 2nd dry, 7–8½*d.*; best light, 8–9½*d.*; salted, 5¼–7¾*d.*; Brazil, dry, 7–10½*d.*; dry-salted, 4½–9*d.*; W. India, salted, 3½–7*d.*; United States, salted, 3½–6½*d.*; E. India, best, 4–13*d.*; 2nd, 1¾–11¼*d.*; 3rd and 4th, 1¼–9*d.*; Australian, salted, 2¾–6*d.*; Cape, wet salted, 2½–7½*d.*; Continental, salted, 3¾–5*d.*; English, 2¾–7*d.*

Seal.—Our imports of seal-skins in 1880 were from:—British N. America, 287,449, 82,781*l.*; United States, 162,189, 425,705*l.*; N. whale fisheries, 54,381, 11,656*l.*; Norway, 54,005, 12,204*l.*; Uruguay, 10,900, 30,180*l.*; other countries, 84,352, 60,752*l.*; total, 653,276, 623,278*l.* In 1879, the total was 964,208 skins. The exports from Christiania in 1879 were 74,090 pieces; to Great Britain, the value was 254,400 *kroner* (of 13½*d.*) in 1878, and 172,900 *kr.* in 1879. Our total imports from Norway rose from 29,912 pieces in 1877, to 63,540 in 1878, and receded to 54,005 in 1880. From the Cape, they were 11,065 in 1877, 15,128 in 1879, and 7731 in 1880. And from Newfoundland, 413,057 in 1879, and 253,656 in 1880. The approximate London market values of seal-skins (not fur seals) are 1*s.* 9*d.*–10*s.* 6*d.* each for Newfoundland, and 2–11*s.* for Greenland.

Sheep.—Our imports of undressed sheep-skins in 1880 were from:—British S. Africa, 1,850,731, 241,915l.; Argentine Republic, 1,245,703, 217,592l.; France, 909,828, 136,217l.; Australia, 816,231, 124,430l.; Germany, 405,101, 51,914l.; Belgium, 336,388, 40,201l.; Turkey, 246,643, 20,821l.; Uruguay, 131,543, 18,102l.; other countries, 844,697, 92,731l.; total, 6,786,865, 943,923l. Dressed, in the same year, from:—Madras, 2,151,533, 192,480l.; Australia, 1,626,355, 81,623l.; Bombay and Sind, 600,347, 46,089l.; France, 560,103, 68,316l.; Bengal and Burma, 160,094, 26,851l.; other countries, 446,116, 55,555l.; total, 5,544,548, 470,914l. Bosnia Serai, in 1879, exported about 10 tons. Shanghai, in 1878, 50,285 pieces (including lamb). Coquimbo (Chili), in 1879, 45 tons (including goat). Bagdad, in 1878, 86,351 pieces, 4071l., to India and Europe (including lamb). Falkland Islands, 1940l. worth in 1879. Cape, 1,480,875 pieces in 1879. Hankow, 7606 pieces, 9276l., in 1879. Tientsin, 206,777 *piculs* (of 133⅓ lb.) in 1878, 8737 in 1879. Mollendo (Peru) 79 *quintals* (of 2 cwt.) in 1878. Mogador, in 1880, 15 bales, 80l., to Great Britain; 345, 1700l., to France; 2, 3l., to Spain. Our imports from the French E. Indies have fallen from 5600 pieces in 1876, to 3762 in 1877, 410 in 1879, and none since; from Italy, from 339,973 in 1876, to 39,751 in 1880; from European Turkey, from 230,922 in 1876, to 63,236 in 1880; from Asiatic Turkey, they have risen from 93,965 in 1876, to 185,543 in 1880; from Brazil, 41,604 in 1876, 2623 in 1877, 5730 in 1880, and none in the intermediate years; from the Argentine Republic, 3,539,589 in 1876, 898,155 in 1879, 1,248,553 in 1880; from the Cape, 1,496,039 in 1877, 1,819,772 in 1880; from India, 3,927,934 in 1876, 2,911,974 in 1880; from Victoria, 1,667,330 in 1876, 1,158,686 in 1880; from New S. Wales, 83,167 in 1878, 36,995 in 1880; New Zealand, 168,984 in 1878, 334,792 in 1880. The approximate London market values of sheep-skins are:—Cape, 10–34s. a doz.; fine wool, 28–59s.; superior, 40–82s.; Mogador, 14–27s.; Buenos Ayres, 4–13d. a lb.; Australian, 4–16d.; tanned E. Indian, best, 2–4s.; ordinary to good, 1s.–2s. 9d.

Walrus.—Our imports of walrus skins from Christiania in 1879 were valued at 7900 *kroner* (of 13½d.).

Commerce in Hides (unenumerated, but chiefly Ox and Cow).—Our imports of undressed dry hides in 1880 were from:—Bengal and Burma, 411,874 cwt., 1,473,720l.; Straits, 48,175 cwt., 110,114l.; Bombay and Sind, 47,546 cwt., 130,094l.; British S. Africa, 34,133 cwt., 128,182l.; Holland, 21,447 cwt., 66,692l.; Brazil, 13,500 cwt., 48,233l.; Germany, 11,764 cwt., 55,860l.; Belgium, 7697 cwt., 24,532l.; Russia, 5938 cwt., 40,977l.; Argentine Republic, 4355 cwt., 14,851l.; France, 3371 cwt.; 11,452l.; Madras, 2601 cwt., 7512l.; other countries, 47,071 cwt., 159,236l.; total, 659,472 cwt., 2,271,455l.

Undressed wet hides, from:—Uruguay, 104,495 cwt., 338,830l.; Brazil, 101,637 cwt., 301,892l.; Australia, 101,371 cwt., 222,903l.; Belgium, 60,426 cwt., 177,356l.; France, 53,934 cwt., 143,667l.; Germany, 32,619 cwt., 77,220l.; Holland, 32,121 cwt., 82,887l.; Argentine Republic, 30,550 cwt., 83,601l.; British S. Africa, 19,217 cwt., 51,547l.; Portugal, 10,502 cwt., 33,229l.; New Granada, 5240 cwt., 19,475l.; Sweden, 4897 cwt., 14,162l.; Denmark, 3657 cwt., 10,032l.; other countries, 21,650 cwt., 51,326l.; total, 582,316 cwt., 1,608,127l.

Tanned hides, from:—United States, 19,923,807 lb., 984,075l.; Australia, 7,595,257 lb., 318,727l.; Madras, 4,995,439 lb., 229,799l.; Straits, 2,778,159 lb., 100,195l.; British N. America, 838,366 lb., 38,835l.; Bombay and Sind, 738,471 lb., 38,258l.; Bengal and Burma, 444,220 lb., 21,024l.; France, 437,415 lb., 39,393l.; Holland, 418,873 lb., 36,811l.; Belgium, 337,579 lb., 24,526l.; China, 239,819 lb., 11,681l.; other countries, 311,024 lb., 16,758l.; total, 39,058,429 lb., 1,860,082l.

Tanned and curried hides, from:—France, 3,850,457 lb., 513,164l.; United States, 2,321,385 lb., 165,877l.; Germany, 1,181,845 lb., 306,133l.; Holland, 329,166 lb., 58,897l.; other countries, 256,123 lb., 29,412l.; total, 7,938,976 lb., 1,073,483l.

Varnished, japanned, or enamelled hides, from:—United States, 297,841 lb., 44,631l.; Holland, 148,695 lb., 40,898l.; Germany, 55,958 lb., 12,623l.; other countries, 153,543 lb., 23,306l.; total, 656,037 lb., 121,458l.

Our exports of hides in 1880 were:—Dry: 179,917 cwt., 630,955l., to Germany; 59,636 cwt., 224,851l., Holland; 44,000 cwt., 160,960l., United States; 17,091 cwt., 56,505l., Russia; 16,898 cwt., 63,307l., Italy; 6000 cwt., 23,218l., Belgium; 5433 cwt., 20,250l., Sweden; 13,854 cwt., 52,038l., other countries; total, 342,829 cwt., 1,232,084l. Raw: 44,673 cwt., 91,383l., United States; 36,772 cwt., 58,282l., Germany; 10,943 cwt., 18,113l., Holland; 3129 cwt., 7031l., Canada; 3017 cwt., 5448l., Belgium; 2262 cwt., 4454l., France; 4465 cwt., 9725l., other countries; total, 105,261 cwt., 194,436l.

Our imports of hides from the undermentioned countries have fluctuated as shown:—

Abyssinia.—Undressed, 7289 cwt. in 1876, 327 in 1878, 2159 in 1879, and 324 in 1880.

Aden.—Undressed, 8190 cwt. in 1876, 113 in 1879, 8294 in 1880.

Algiers.—Raw, 2,051,701 *kilo.* (of 2·2 lb.) in 1879.

Argentine Republic.—Undressed, 94,479 cwt. in 1877, 32,961 in 1879, 34,905 in 1880.

Austro-Hungary.—Vienna, 24,672 metrical *centners* in 1878, 48,950 in 1879; Fiume, raw, 1400 *kilo.* in 1879.

Bahamas.—167l. worth in 1879.

Barbados.—363*l.* worth in 1877, 913*l.* in 1878.

Belgium.—Undressed, 51,069 cwt. in 1877, 82,021 in 1878, 68,123 in 1880. Dressed, 176,635 lb. in 1878, 418,906 in 1880.

Brazil.—Undressed, 137,351 cwt. in 1878, 115,137 in 1880. Pernambuco in 1878–9 exported, dried, 31,717 *kilo.* to Great Britain, 28,077 France, 25,606 Portugal, total value 3002*l.*; salted, 383,691 *kilo.* Great Britain, 937,976 United States, 585,868 France, 40,770 Spain, 463,269 Portugal, total value 75,523*l.*; in 1880, 61 tons, 2267*l.* Maceio exported in 1877, 4728 pieces (average 28 lb. each) to Great Britain, 1440 New York and Lisbon; in 1879, 36,775; in 1880, 11,405. Bahia exported 1,432,864 *kilo.* in 1877–8, and 1,773,965 in 1878–9, principally to the United States and Germany. Santos exported 397,000 *kilo.* in 1879. Ceara exported in 1878, 372,808 *kilo.* to England, 31,966 Havre, 775,863 Hamburg, 7800 New York.

British India.—Undressed, 281,198 cwt. in 1876, 463,764 in 1880; dressed, 14,835,979 lb. in 1878, 6,178,370 in 1880.

Bulgaria.—Rustchuk, in 1879, exported 254,196 *kilo.* (250 tons) to Austria.

Canada.—Dressed, 939,759 lb. in 1876, 372,359 in 1879, 1,066,043 in 1880.

Cape.—Undressed, 15,370 cwt. in 1876, 44,503 in 1878, 29,442 in 1880.

Central America.—Undressed, 72 cwt. in 1876, 1113 in 1878, 356 in 1880.

Chili.—Undressed, 318 cwt. in 1876, 17,042 in 1879, 1566 in 1880; dressed, 33,026 lb. in 1876, 3929 in 1877, 199,965 in 1878, 224 in 1879, 2930 in 1880.

China.—Undressed, 5671 cwt. in 1876, 60,871 in 1878, 2705 in 1880. Hankow exported in 1879, 7797 pieces, 1656*l.*; Kiungchow, 490 *piculs* (of 133⅓ lb.), 818*l.*; Newchwang, 17,665 pieces; Tientsin, 4354 *piculs*; Canton, in 1878, 653 pieces of skins, 873¾ *piculs* of hides.

Costa Rica.—San José exported 308,794 lb. in 1879.

Denmark.—Undressed, 20,806 cwt. in 1877, 5632 in 1880; Copenhagen exported 1,166,172 lb. to Great Britain in 1878.

Ecuador.—Undressed, 680 cwt. in 1876, 18 in 1877, 115 in 1879, 89 in 1880. Guayaquil exported in 1878, 5711 *quintals* raw, 17,133*l.*, to the United States, and 12,504 halves tanned, 8752*l.*, to S. America; and in 1880, 8859 *quintals* raw, 22,148*l.*, and 4861 tanned, 2916*l.* Manabi, in 1878, exported 1321 *quintals*, 3963*l.*

Egypt.—Undressed, 1250 cwt. in 1877, 718 in 1878, 1286 in 1880. In 1879, the values were 620*l.* to Austria, 380*l.* France, 1950*l.* Great Britain, 45,500*l.* Greece, 280*l.* Italy, 62,500*l.* Turkey.

Falklands.—Undressed, 4315 cwt. in 1878, 2679 in 1880. The value of the exports was 5020*l.* in 1879.

France.—Undressed, 26,866 cwt. in 1876, 57,305 in 1880; dressed, 2,727,190 lb. in 1876, 4,338,485 in 1880. Calais in 1878 sent 2188 *kilo.* prepared to Great Britain, and 76,811 *kilo.* in 1879.

French E. Indies.—Dressed, 24,600 lb. in 1876, 12,713 in 1877, none since.

Gambia.—Exported 15,380 pieces in 1878.

Germany.—Undressed, 45,002 cwt. in 1876, 21,143 in 1878, 44,383 in 1880; dressed, 1,269,143 lb. in 1876, 954,578 in 1878, 1,318,659 in 1880. Hamburg sent to Great Britain, 33,458 cwt. dry and salted in 1877, 13,972 in 1879. Königsberg exported 1535 cwt. raw in 1878, 424 in 1879.

Greece.—Dressed: Syra in 1877 sent 60,247*l.* worth to Turkey, 23,259*l.* to the Danubian Principalities, 2748*l.* to Austria; in 1879, 492*l.* Turkey, 251*l.* Austria, 200*l.* Russia.

Guatemala.—Exports in 1877, 62,343 *dol.* worth; in 1878, 844½ *quintals* to England, 1293 France, 2476 Germany, 822 New York, 149 California; 1879, 412,605 Germany, 12,360 New York.

Hawaiian Islands.—Exports 1880, 24,885 pieces.

Holland.—Undressed, 55,705 cwt. in 1876, 53,568 in 1880; dressed, 941,372 lb. in 1876, 896,734 in 1880.

Java.—Exports 1878–9, 357,353 pieces and 1240 *piculs* to Holland, 7212 pieces to the Channel for orders, 1200 pieces to France, 7369 pieces to Italy, 5695 pieces and 872 *piculs* to Singapore.

Madagascar.—Undressed, 252 cwt. in 1877, 3088 in 1879, none since.

Mauritius.—Undressed, 5341 cwt. in 1876, 2945 in 1880.

Morocco.—Undressed, 0 in 1877, 5445 cwt. in 1878, 1014 in 1880. Tangiers exported in 1879, 2727 cwt., 6000*l.*, to Great Britain; 1818 cwt., 4365*l.*, France; 21 cwt., 42*l.*, Spain. Mogador, in 1880, sent 44 bales, 150*l.*, to Great Britain; 667, 2250*l.*, France; 243, 770*l.*, Portugal.

Natal.—Undressed, 32,555 cwt. in 1876, 17,496 in 1878, 23,908 in 1880.

New Granada.—Undressed, 12,217 cwt. in 1878, 574 in 1879, 6059 in 1880.

New S. Wales.—Undressed, 9386 cwt. in 1878, 79,972 in 1880; dressed, 2,257,041 lb. in 1877, 1,694,015 in 1880.

New Zealand.—Undressed, 39 cwt. in 1878, 6335 in 1880; dressed, 140,448 lb. in 1878, 446,102 in 1880.

Persia.—Bushire exported in 1879, 4000 *rupees'* worth to England, 5000 *r.* India; Lingah, 2800 *r.* India, 1950 *r.* Persian coast; Bahrein, 6000 *r.* Koweit, Bussora, and Bagdad.

Peru.—Undressed, 2859 cwt. in 1876, 622 in 1878, 1235 in 1880. Mollendo exported 538 *quintals* in 1878, and 1307 *q.* dry in 1879.

Philippines.—Undressed, 1024 cwt. in 1876, 102 in 1880. Manilla, in 1879, exported 7976 *piculs*, 12,761*l.*, to China and Japan.

Portugal.—Undressed, 17,456 cwt. in 1877, 10,983 in 1880.

Queensland.—Undressed, 1315 cwt. in 1879, 5019 in 1880.

Roumania.—Galatz exported 341 bales in 1879.

Russia.—Undressed, 482 cwt. in 1876, 6020 in 1880; dressed, 88,225 lb. in 1876, 46,694 in 1880. Riga shipped 14,839 *poods* (of 36 lb.) in 1877, 11,311 in 1879. Poti, in 1877–8, sent away 5654 *poods*, and 2149 from Persia.

Saigon.—Exports in 1879, 10,582 *piculs.*

San Domingo.—Exports in 1878, 630 pieces to Great Britain, 490 France, 3100 Italy, 3980 Spain, 460 United States, 560 W. Indies; in 1880, 1340 Italy, 2541 Spain, 7142 United States, 97 W. Indies.

S. Australia.—Dressed, 38,108 lb. in 1878, 303,143 in 1880.

Spanish W. Indies.—Puerto Rico exported in 1878, 167 *quintals* United States, 5673 Spain, 637 Germany.

Straits Settlements.—Undressed, 28,444 cwt. in 1876, 48,213 in 1880; dressed, 603,389 lb. in 1876, 2,778,159 in 1880.

Surinam.—Exports in 1878, 9221 *kilo.*

Sweden and Norway.—Christiania exported 95,200 *kroner* worth in 1875, 4200 *kr.* in 1878. Gothenburg exported 10,960 cwt. in 1879.

Tasmania.—Dressed, 65,803 lb. in 1878, 38,141 in 1880.

Tripoli.—Bengazi, in 1878, sent 50,000 pieces, 4000*l.*, to Malta. The value of the exports was 2000*l.* in 1879, and 4500*l.* in 1880.

Turkey.—Aleppo exported in 1878, 181 tons, 10,824*l.*, to France; 5, 320*l.*, Italy; 11, 704*l.*, Austria; 52, 3328*l.*, Turkey; 12, 768*l.*, Egypt. Thessaly exported 15,000*l.* worth in 1880. Samos sent 19,300*l.* worth tanned to Turkey and Egypt in 1879. Van exported 1500*l.* worth in 1879. Kerasund shipped by steamer in 1879, 557 bales, 3899*l.* Trebizond in 1879 sent 940 bales (of 12 and 60 pieces), 6580*l.*, to Turkey; 1567, 10,969*l.*, France; 501, 3507*l.*, Russia; 80, 560*l.*, Greece. Dedeagatch, in 1879, exported 1300 bales, 40,000*l.* Alexandretta, in 1879, sent 280 tons, 16,800*l.*, to France; 3, 180*l.*, Austria; 10, 600*l.*, Russia; 96, 6720*l.*, Turkey; 29, 2030*l.*, Egypt. Adana, in 1879, sent 250 tons, 7500*l.*, to France; 140, 4200*l.*, Turkey; 27, 810*l.*, Greece. Jaffa exported 18,000 *okes* (49,500 lb.), 666*l.*, for Turkey in 1879.

United States.—Undressed, 115,767 cwt. in 1876, 7888 in 1879; 14,358 in 1880; dressed, 16,716,711 lb. in 1879, 22,543,033 in 1880. Savannah exported 8758 bundles in 1880. Galveston exported in 1879–80, 9878 bales and 7510 single, dry; and 6905 bundles wet-salted. Texas State in 1878–9 exported 28,104,065 lb., 562,081*l.*

Uruguay.—Undressed, 116,738 cwt. in 1876, 65,846 in 1879, 104,691 in 1880.

Venezuela.—Puerto Cabello exported in 1879, 10,126 *kilo.* to Great Britain, 88,717 Germany, 75,794 United States, 5756 France, 696 Holland, 1023 Spain. Ciudad Bolivar sent 35,562 pieces, 762,234 lb., to New York in 1879.

Victoria.—Undressed, 0 in 1878, 2710 in 1879, 8705 in 1880; dressed, 3,506,562 lb. in 1876, 5,096,696 in 1880. The values of the exports in 1878 were 9417*l.* hides, and 19,706*l.* skins and pelts.

(See Feathers, Fur, Hair, Leather.)

SMALLWARES (Fr., *Tissures*; Ger., *Klein-*, *Spiel-*, or *Nürnberger-waaren*).

Mechanical inventions during the past century have revolutionized the aspect of society in nearly every one of its phases. Amongst the most important class of changes that has resulted, is the subdivision and rearrangement of labour for the production of articles of merchandize. The facilities which the manufacturer has acquired for infinitely varying his productions and increasing the quantity, has done much to necessitate a reorganization of the means of distribution. The consequence is that terms formerly distinctive of certain occupations are falling into disuse, or changing their signification. Illustrations of this fact may be found in connection with the trades dealing in materials for apparel. A "draper" formerly meant specifically a dealer in woollen cloth; subsequently it became generic, and an adjective was required, such as linen or woollen, to clearly define its meaning. More recently it has quite lost its original signification, the person whom it formerly indicated having become a "clothier." "Haberdashery" was the term in use some time back for the branch of trade dealing more particularly with fabrics destined for feminine wear, and the numerous small etceteras pertaining thereto. This term has been almost abandoned in favour of "draper," the one cast aside by the modern "clothier." In place of the haberdasher, there has sprung up another distinctive business character, the "smallware dealer," who has taken a portion of the haberdasher's specialities, and combined therewith many other articles having a general likeness, or similar origin. Out of this amalgamation of old and new, the modern smallware business has sprung. Under the term "smallwares" are comprehended a great variety of articles, comparatively insignificant in themselves, but important as accessories necessary to complete and perfect the use of other things.

Only a rough classification of smallwares can be attempted, as whatever principles be adopted, those of one division will frequently be found in another with only slight specific variations. Smallwares, as ordinarily understood, are mainly allied to textiles, in the materials of which they are composed, the manner of their fabrication, and their ultimate uses. They may be divided into three great classes: (1) for purposes of attire, (2) for upholstery uses, and (3) in which may be grouped the numerous articles ordinarily denominated fancy goods.

The first named division is probably the most extensive. In this, "braids" form a considerable class of themselves, as they are produced in all materials, gold, silver, silk, wool, worsted, alpaca, mohair, and cotton. Most of these are made in various widths (¼–2 in.), and in numerous shades of every colour, according to the requirements of popular taste. Manchester, Derby, Leicester, and Nottingham are the chief centres of manufacture in England, whilst great quantities are produced also in France and Germany. The texture of plain braids is usually alike on both sides. The best qualities are generally made up in ¼-gross cards or knots, four of which are put in a box; the commoner are made up in ¼-gross pieces, four pieces in a package. These lengths ought to be full, but too often they range from $\frac{1}{36}$ to $\frac{1}{12}$ short of the nominal length. The blame for this is frequently, and nearly always unjustly, placed upon the manufacturer, who, however, could rarely, without incurring detection, deliver short-length goods to his contracts. The custom is to quote for proper or full lengths, when the buyer gives instructions for them to be made $\frac{1}{36}$, $\frac{1}{18}$, or $\frac{1}{12}$ less, a corresponding deduction being made from the full-length quotation prices. This is one of the vicious results of excessive and unscrupulous competition, and is a custom against which the retailer should be carefully on his guard, as it is on him that the loss falls when undetected. "Bindings" are a kindred article to braids, but usually of a rather different texture; the two sides are not alike, the front having a diagonal or "herring-bone" twill, whilst the back is plain. "Ferreting" is an old name for a silk flannel-binding of the latter texture. These are not in such extensive use at present as formerly. "Cords" are composed of the same materials as braids, and, as their name indicates, are round instead of flat. They are generally black, though sometimes made in colours; and may be had either with or without cores. They are made up in a similar manner to braids, in gross packages. In connection with these may be mentioned elastic cords and braids, which, instead of having an inelastic fibrous core, have substituted therefor fine strips of indiarubber, around which the covering is plaited as in those containing a core. These strips vary in number and thickness as may be required, from a single one in cords to whatever number may be demanded by the width of braids. They are mostly black, but small quantities are also produced in colours. They are generally carded in lengths varying from ¼ to a full gross, or even more, according to width and thickness. Leicester, Derby, and Manchester are the places of manufacture. The remarks concerning lengths made in connection with braids apply also in this case. Sometimes, for trimming purposes, braids are made in variegated colours, and in wave and vandyked or other fancy forms; but these changes are not frequent, and do not prevail long at a time.

"Trimmings" constitute a large proportion of the smallwares of dress, and include "gymps," "fringes," "ornaments," "tassels," and fancy buttons, covered and plain. The first are usually made from the cords already referred to. These are wrought up into numerous tasteful forms, and sometimes ornamented with beads. The widths vary from very narrow to several inches wide. They are made up on cards of various lengths. "Ornaments" are a kindred trimming, consisting of single objects or sets; they vary greatly in price, according to the quantity of work in them and the value of material. They are made by the same manufacturers as gymps. In England, these are chiefly found in London, Coventry, and Nottingham, but great quantities are imported from France and Germany, when fashion is in their favour. "Fringes" are of various materials, widths, forms, and colours, plain, knotted, and otherwise ornamented. These are usually carded like gymps, in varying lengths. Coventry, Leicester, Nottingham, Derby, Macclesfield, and other places in this country produce them when in demand, along with several districts on the Continent. "Trimming-buttons," when covered with silk or other materials, are generally made by the manufacturers of gymps and ornaments. Plain, that is uncovered, buttons, in ivory, bone, glass, metal, vegetable ivory, or composition, are put up on cards and boxed; Birmingham is a great seat of manufacture, and has numerous competitors in several centres in France and Germany (see Buttons, pp. 557–571).

Yarns in silk, wool, worsted, merino, and cotton, form a considerable division of smallwares. They include knitting, mending, netting, crochet, and a large number of fancy yarns. The first-named material, being costly, is not in extensive use compared with the others. Wool yarns are produced in great variety, from common coarse knittings to fine Saxony and Berlin wools of a very superior quality, which are fabricated into articles of comparative luxury. An almost endless variety of colours, shades, mixtures, and variegated yarns are produced to meet public demand. Worsted, save for knitting purposes, is not in much request. "Mendings" are adjuncts of the hosiery trade, and their character depends upon what is in vogue for the fabrication of the medium and lower classes of hosiery. As a rule, there is always a considerable production in worsted, wool, and merino, and occasionally in cotton yarns, for the smallware section of the trade. Leicester, Wakefield, Halifax, Bradford, and other places of less note in the different woollen manufacturing districts, are the chief centres of production. A fair quantity is also imported from the Continent, chiefly from Germany; but this is likely to diminish, owing to the superiority of the home productions, from the improved methods of dyeing and finishing that have of late been adopted.

"Sewings" are chiefly composed of silk, including "patent silk," cotton, and linen threads. These embrace every variety of colour, and count or degree of fineness, to suit the multifarious purposes in which they are consumed. Silk thread was formerly more extensively used, relatively considered, than at present. It was then composed of net silk, and was mostly sold in small skeins by weight, colours commanding a higher price than blacks and whites. Derby, Leek, Congleton, Macclesfield, and Coventry, had almost a monopoly of its production at that time. During the past 15 years, however, it has to a great extent been superseded in public favour by the greater cheapness and excellence of "patent silk" sewings, produced from silk waste (see p. 1755). The article obtained from the latter is more uniform in thickness, and better adapted for use in the sewing-machine now so extensively employed. Bradford, Leicester, and Derby, are the chief places of production, though several isolated mills are to be found in other parts of the country. The production of sewing-cottons has become a large and very important branch of trade, and the high degree of excellence to which it has been carried in this country has secured for our manufacturers a practical monopoly of the trade. The yarns from which these threads are made are chiefly spun in Bolton and Manchester, from the best classes of cotton, and which are nearly always combed, not carded, thereby securing an equality in the length of fibre, which yields a thoroughly level and uniformly strong yarn, highly essential for the production of good sewing-cottons. The machinery from which they are produced is mainly that of the series used in the manufacture of twines (see Rope, pp. 1595–1610), modified in size; the operations are nearly identical, consisting in doubling, twisting, cabling, gasing, and polishing. The last process of filling the reels is effected in a very ingenious machine, which automatically performs all operations necessary for supplying, filling, measuring, and discharging the reels ready for packing. Various qualities are produced, depending chiefly upon the class of cotton from which the single yarn is made; they are generally three-, six- or nine-fold, the lowest fold being the commonest quality, and rising in proportion. The numbers run from 4's to 200's, which latter is almost as fine as human hair. The lengths upon the reels vary from 200 to 1000 yd., or even more; as a rule, medium lengths are found the most useful, the small reels requiring to be replaced too often when used in the sewing-machine, the large ones being too heavy for the proper tension necessary for good work. The reels are made up in packages of one dozen each, and sold by the gross. The chief centres of production are Paisley, Manchester, Bolton, Leicester, and a few other places. In the first-named district there are some very large firms, who have also branch establishments in the United States. The produce of the English establishments is exported to all parts of the world, in spite of, in some cases, almost prohibitory tariffs. Linen threads are now but little used in the production or manufacture of articles of clothing, but retain their place for upholstery, cordwainers', and saddlery uses, where great strength is required. Formerly this thread was made up for consumption in small skeins, and sold by weight; but it is now chiefly put on reels, each reel containing a given weight of thread by which it is sold, the length varying with the count or degree of fineness. Belfast and district produces the greatest portion of linen thread, though some is manufactured in Glasgow, in several towns in Yorkshire, and in a few other places.

As adjuncts to the articles above described, and always found in connection with them, must be mentioned needles for plain and machine sewing; thimbles, pins, hooks, shuttles, &c., for knitting, netting, crochet, tatting, and other fancy-work purposes; hair-pins, combs of every variety, metallic ornaments, and an endless catalogue of trifles, changing their appearance, but not their use, every season. These articles are produced in metal, ivory, bone, and wood, and in a variety of fancy forms. Redditch maintains its pre-eminence as the centre of production for needles of all descriptions, whilst Birmingham manufactures nearly all the rest of the articles named.

Another class of goods that, though kindred, properly speaking form a distinct branch, but are often found in connection with the preceding, are upholsterer's smallwares, which include fringes in silk, worsted, and cotton, for cornices, hangings, and curtains; plain, knotted, balled, and otherwise ornamented. These are made in various widths, according to intended use or requirement. Curtain-borderings, gymps, cords, bell-ropes, bands, loops, laces, bindings, chair- and ladder-webs, blind-lines and tassels, ottoman- and pillow-tassels, chair-gymps, plain and waved: these are made in silk, worsted, cotton, and jute. Appertaining to them are ornamental buttons, plain, covered, and gilt, fancy-gilt nails, rings, hooks, pins, &c. The trimmings are chiefly made in London, Manchester, Leicester, and Coventry; and the metallic articles in Birmingham.

The fancy department of a smallware establishment is made to include a large assortment of articles in many respects quite incongruous, but which are usually thus grouped because of their small importance and limited demand not warranting any other arrangement. These include perfumes (see pp. 1523–32), fancy soaps (see Soap), pomades, hair-, tooth-, and nail-brushes, and other toilet requisites. Small bags, satchels, glove-boxes, handkerchief-cases, purses, jewel-cases, trinket-boxes, jet and vulcanite ware, and the innumerable small things denominated *articles de Paris*, coming from that city and other Continental centres of production of fancy wares. To these have latterly been added kindred classes of articles coming from Eastern countries, India, China, and Japan.

It will be obvious that the foregoing is only an inadequate representation of the numberless trifling adjuncts to our necessaries or luxuries, which the growing wealth and refinement of the age have called, and are still calling into existence, and which, for want of more clear and definite means of classification, are being grouped under or attached to a division of trade that has hitherto been clearly defined and widely known as the "smallware trade." To make a complete enumeration of the additions that have occurred would require a volume. The principle of change of which these articles are the outcome is still active, and its operations in the future will continuously lead up to new developments in the products of industry, new groupings of the objects of merchandize, and new methods of conducting business. R. M.

SOAP, RAILWAY-GREASE, AND GLYCERINE.

Soap (Fr., *Savon*; Ger., *Seife*).—Although soap has been made and used for many centuries (it is mentioned by Pliny, and the remains of a soap-factory, with lime, &c., remaining in it, are still shown in Pompeii), the principles which should guide its manufacture have only been discovered in quite recent times. A proper comprehension of these principles is indispensable to every one who would become a successful manufacturer, because soap-making is essentially a chemical operation; but as they can only be dealt with very briefly here, the reader unacquainted with them is recommended to consult any modern elementary work on chemistry.

Although, in ordinary parlance, the term "soap" denotes simply that combination of fatty matter with alkali which, by its detergent properties, aids in the removal of grease and dirt in washing (in which sense alone will it be used in this article), it is highly important to remember that "soaps" as a class are, strictly speaking, "salts," using that term in the chemical sense. Every salt contains an acid and a base, having opposite properties, and producing by their union a third substance differing from either. Thus Glauber's salts, sulphate of soda, or sodium sulphate (all are synonymous terms), is a compound of sulphuric acid and soda, or

$$\begin{array}{ccc} \textit{Salt} & = \textit{acid} & + \textit{base.} \\ \text{Sulphate of soda} & = \text{sulphuric acid} & + \text{soda.} \end{array}$$

All the neutral fats of commerce which are used in soap-making, such as tallow, palm-oil, coconut-oil, cotton-seed-oil, and greases of various kinds, are also, from a chemical point of view, "salts" of which the "base" is (not soda but) glycerine, and the "acid" (not sulphuric but) a mixture of various "fatty acids," which by proper means, may, if desired, be separated from each other, and prepared in a state of greater or less purity. Hence,—

$$\begin{array}{ccc} \textit{Salt} & = \textit{acid} & + \textit{base.} \\ \text{Neutral fat (e. g. tallow)} & = \text{various fatty acids} & + \text{glycerine.} \end{array}$$

Theoretically, soap-making is nothing more than turning out the glycerine base by a strong mineral base, or alkali, such as potash or soda. Hence,—

$$\text{Neutral fat} + \text{Alkali} = \{\text{Fatty acids} + \text{Alkali, or "Soap"}\} + \text{Glycerine.}$$

As, however, certain oils much used by the soap-maker are already fatty acids, and contain no glycerine (e. g. oleic acid, sometimes erroneously called oleine, a bye-product of the candle-factory), the formation of soap from them is simply a direct combination of fatty acids with the proper proportion of alkali. This process will be dealt with in describing special soaps.

While, therefore, chemically speaking, any combination of fatty acids with a mineral base is a "soap," in practice no soaps are made except with potash or soda, as only those soaps are soluble in water; all others, such as those formed by the union of fatty acids with lime, baryta, or even with the oxides of the metals, as lead, copper, &c., are insoluble in water, though some of them are used in pharmacy: a "plaster," for instance, is usually a soap from the fatty acids of soft oils, with oxide of lead as a base, and chemically speaking, is an oleate of lead.

A further acquaintance with the theory of salts will make it clear that, in the case of mineral acids and bases there is a certain definite proportion peculiar to each, in which (or in a simple multiple of which) they combine with each other. Thus 31 parts of pure caustic soda (100 per cent.) require 49 parts of oil of vitriol (100 per cent. sulphuric acid) to form the neutral salt, sulphate of soda, and in the operation, 9 parts of water are formed, the hydrogen of which is derived from the acid, and the oxygen from the base. The combined weight of the products is of course exactly equal to the sum of the weight of the constituents, or,—

$$31 \text{ parts soda} + 49 \text{ parts sulphuric acid} = 71 \text{ parts sulphate of soda} + 9 \text{ parts water.}$$

This number, called the "combining proportion" or "equivalent" of each substance, is determined by chemical research. It can scarcely be too strongly insisted on that the fatty acids have their equivalents also; thus the determination of the quantity of soda necessary for their saponification is a matter of calculation, and hence the varying equivalents of the different fatty acids is the real explanation of the well-known fact that the "yield" of soap is so different from various fats.

To revert for a moment to the combination of sulphuric acid and soda,—considerable heat is evolved in the process, which has its parallel in saponification; further, if either constituent had been in excess, there would have resulted a mixture of neutral sulphate of soda with the remainder of whichever constituent was in excess. If, however, twice 49, or 98, parts of sulphuric acid had been taken, an acid sulphate, or bisulphate, of soda, would have been formed. The fatty acids are remarkable in this respect, that their combining proportions or equivalents are much higher than those of mineral acids. Thus to combine with 31 parts of soda (100 per cent.), 284 parts of stearic acid are required, 282 parts of oleic acid, 256 parts of palmitic acid, and only 200 parts of lauric acid, one of the chief fatty acids of coco-nut-oil. Hence, while tallow gives the least "yield" of soap, among the fats usually employed, coco-nut-oil gives the most, and palm-oil occupies an intermediate position.

What has been said above with regard to 31 parts of soda, applies with equal force to potash, replacing 31 by 47, which is the combining proportion of potash.

From the explanation now given, it is easy to calculate the quantity of soda or potash necessary to completely saponify,—

100 lb. of	Soda, 100 per cent.	Potash, 100 per cent.
Tallow	10·50 lb.	15·92 lb.
Palm-oil	11·00 „	16·67 „
Coco-nut-oil	12·44 „	18·86 „
Oleic acid	10·52 „	15·95 „

It is obvious that the proportion of alkaline ley to be used must be regulated by its strength; thus, if ley containing 20·0 per cent. soda be used, i. e. $\frac{1}{5}$ its weight of soda at 100 per cent., five times the given weights must be used for 100 lb. fatty material.

It will be convenient here to explain briefly the causes of the differences in combining proportion among the various fats. Their fatty acids are all composed of the three elements, carbon, hydrogen, and oxygen, combined in different proportions of thetwo first-named, but all containing the same quantity of oxygen. They may be arranged in a series, known as the "adipic," of which the lowest term, formic acid, contains 12 parts by weight of carbon, 2 parts hydrogen, and 32 parts oxygen. The other terms of the series differ from each other by 12 parts carbon and 2 parts hydrogen. The following table gives some of the principal terms of this series, $C_nH_{2n}O_2$, from which, it is clear that the differences in their equivalents are due to the differences in the quantities of carbon and hydrogen entering into their composition, which also affect their melting- and boiling-points.

TABLE A.—THE CHIEF FATTY ACIDS OF THE SERIES $C_nH_{2n}O_2$ OCCURRING IN NATURAL FATS.
(Some intervening terms omitted.)

Name.	Formula.	Equivalent.	Fusing-point C.	Boiling-point C.	Natural Fat.
Formic acid	CH_2O_2	46	−6·0°	105.3°	
Acetic „	$C_2H_4O_2$	60	17·0	117	
Butyric „	$C_4H_8O_2$	88		164	Butter.
Caproic „	$C_6H_{12}O_2$	116	−9·0	200	Volatile acids of coco-nut-oil, &c.
Oenanthylic acid	$C_7H_{14}O_2$	130		212	
Caprylic „	$C_8H_{16}O_2$	144	15·0	236	
Pelargonic „	$C_9H_{18}O_2$	158	—	260	
Capric or Rutic acid	$C_{10}H_{20}O_2$	172	30·0	..	
Cocinic acid	$C_{11}H_{22}O_2$	186	35·0	..	Fixed acids of coco-nut-oil, &c.
Lauric „	$C_{12}H_{24}O_2$	200	43·0	..	
.. .. ..	$C_{13}H_{26}O_2$	214	47·0	..	
Myristic „	$C_{14}H_{28}O_2$	228	53·8	..	
.. .. ..	$C_{15}H_{30}O_2$	242	56·0	..	
Palmitic acid	$C_{16}H_{32}O_2$	256	62·5	..	Palm-oil.
Margaric „	$C_{17}H_{34}O_2$	270	66·0		
Stearic „	$C_{18}H_{36}O_2$	284	69·2	..	Tallow.
Cerotic „	$C_{27}H_{54}O_2$	410	79·0	..	Bees'-wax.
Melissic „	$C_{30}H_{60}O_2$	452	89·0	..	

The fatty acid of the fluid constituent of most natural fats and oils, called oleic acid, belongs to another series, $C_nH_{2n-2}O_2$, known as the "acrylic;" its formula is $C_{18}H_{34}O_2$, and its equivalent is 282.

For reasons which are not within the scope of the present article, the true chemical equivalent of these fatty acids is always taken at thrice the above numbers. The acids can all form salts containing once, twice, or thrice 31 parts of soda, and it requires *three* of the above equivalents of any acid to form a neutral fat with *one* equivalent of glycerine, so that the process of the saponification of a neutral fat by caustic soda may be thus represented,—

(3 equivalents, stearic acid and soda.)

$$\underset{\text{Tristearine.}}{C_3H_5(C_{18}H_{35}O_2)_3} + \underset{\text{Caustic soda.}}{3NaHO} = \underset{\text{Sodium stearate or soap.}}{3(C_{18}H_{35}O_2Na)} + \underset{\text{Glycerine.}}{C_3H_5(OH)_3}$$

(1 equivalent, glycerine.)

$$890 + 120 = 918 + 92$$

Consult also Candles, pp. 579–80. Glycerine will be treated of separately at the end of this article (pp. 1798–1802).

Raw Materials.—The raw materials employed in the production of pure soaps are (1) fatty matters of various kinds, (2) rosin, or colophony, (3) solution of caustic soda or potash. In the article Oils and Fatty Substances, will be found full descriptions of the different kinds of fats and oils suitable for soap-making; on pp. 1458–62, are directions for refining and bleaching them, preparatory to their saponification; and on pp. 1462–77, are instructions for their analysis, the detection of adulterants, &c. Rosin will be discussed under Resinous and Gummy Substances (see also Wax), and Alkali contains a full account of the manufacture of soda and potash. But very few general remarks, therefore, are necessary in treating of raw materials, and these will be especially practical in their character.

Since the selection of the raw material depends entirely upon the kind of soap which it is desired to produce, it may be remarked at the outset, that soaps are divided into two classes, "hard" and "soft." For the production of what is technically called "soft soap," it is necessary to use potash as an alkali, to the almost entire exclusion of soda. Potash soaps are deliquescent, and do not dry up when exposed in solution to the air, but retain water enough to form a soft slimy jelly. Soda soaps neither retain so much water, nor absorb it from the air, but harden when exposed, partly from loss of water. This difference is best seen in the case of the salts of pure fatty acids thus:—

100 parts dry potassium oleate absorb 162 parts water from the air.
100 „ „ palmitate „ 35 „ „
100 „ sodium stearate „ 7½ „ „

In the manufacture of soft soap, oils that are fluid or semifluid at the ordinary air-temperature are usually employed, and especially linseed- and other seed-oils, and the cheaper varieties of fish-oils. Certain oils make a hard or a soft soap, according as the alkali employed is soda or potash, or, in some cases, a mixture of both. As a general rule, not more than ¼ of the potash in a soft soap can be replaced by soda (for cheapness sake) without impairing the quality of the soap.

Hard soaps invariably contain soda as their base, and, *ceteris paribus*, the hardness varies inversely as the quantity of water in the soap. An oil as fluid as commercial oleic acid will produce a hard soap with soda, if the process be so conducted that but little water is present during the operation. Tallow, mixed with varying proportions of rosin, is employed for household "yellow" soap; kitchen-grease, bone-fat, discoloured lard, and other greases, with rosin, for inferior grades of the same; while the same greases, and palm-, cotton-seed-, olive-, coco-nut-, and palm-kernel-oils, are used either alone, or in various combinations, for the different kinds of mottled soap. The raw materials for soaps for special manufacturing, toilet, and other purposes, will be mentioned when treating of those soaps.

It has been already noticed that coco-nut- and palm-kernel-oils combine with a larger quantity of soda than any other known fat, and hence that the yield of soap from these oils is greater than from other fats. Further, the soap so produced has the power of combining (and making a hard soap) with more water than can ever be communicated to tallow soap, a property which has frequently given rise to dishonest traffic. This soap is more soluble in water than any other, and requires a much larger quantity of common salt to separate the excess of water from it. In technical language, it is said to "work close." Reference to the table on p. 1765 will show the reason for this. Coco-nut-oil contains a number of low terms of the fatty-acid series, whose salts are so very soluble, that even the lime and baryta salts of the lower among them are quite soluble in water, just as are the lime and baryta salts of formic and acetic acids, the lowest terms of all.

Among the raw materials used by the soap-boiler, not enumerated under Oils, are various bye-products of other manufactures, among which may be mentioned—the oleine or oleic-acid from candle-works (see Candles, pp. 580, 584, &c.); the grease recovered from washwaters of woollen factories, pp. 1155–6, which is very apt to contain unsaponifiable oils, and should be employed with caution; the "foots" from various oil-refineries, which either contain strong mineral acids (p. 1460) or are partly-formed soaps when an alkaline refining process has been used (p. 1460); waste fats recovered by carbon bisulphide or petroleum-spirit (pp. 1454–5), also liable to contain unsaponifiable oils; "suint," or the grease derived from natural wool, accompanied by potash salts; and, especially in France, the yolks of eggs, see pp. 1365–6 (of which the whites have been used in the preparation of albumen), which contain a considerable percentage of fatty matter. This list might be largely increased.

The value of soap-making material is best ascertained by saponifying a weighed quantity (say 5–10 *grm.*) with soda, dissolving the soap in water, decomposing it with a mineral acid, and then washing, drying, weighing, and examining the resultant fatty acids, as is described on pp. 1462–3 of Oils, and, in a modified form, on p. 1794 of this article.

Rosin (see Resinous and Gummy Substances, p. 1680).—The kind used in soap-making is known as colophony. The lighter shades only can be used for better-class soaps. Such are liable to contain a little turpentine, which, to some slight extent, injuriously affects the hardness of the soap; and they are apt to become unpleasantly soft in very hot weather. Opaque rosins contain turpentine, and, in rare cases, water. Dark rosins may be improved in colour, and deprived of suspended impurity, by being melted, allowed to settle, and then boiled on a weak solution of common salt. Dark rosin may be distilled with steam under a pressure of 10 atmos. to make it nearly white for soap-making. Like many other distilled products, however, it has a tendency, both alone and in combination, to oxidize rapidly, and deteriorate in colour. When fine rosin is unusually dear, however, this process may be employed with advantage.

Chemically speaking, rosin is an acid, or mixture of acids (picric, sylvic, colophonic, and pimaric) whose general formula is $C_{20}H_{30}O_2$, and their combining proportion (with 31 parts soda) is 302. Rosin decomposes carbonate of soda, and combines instantly with caustic alkali, forming in each case a so-called rosin soap, which is a thick, slimy, brown mass, containing 15·8 per cent. of dry soda; its attraction for water is so great as to become liquid on exposure to air, even though previously dried artificially.

Rosin is never employed alone for soap, but always in conjunction with fats; it has been described as an ameliorator, and is also a cheapener; it contributes to the popular qualities of soap, rendering it more readily soluble, and forming a copious lather in laundry and household soaps. In them the proportion varies from 15–20 per cent. of the fatty matter employed, to an equal weight, or even more. Hard soaps for manufacturing purposes rarely contain it. It may be saponified alone and the result mixed with a fat-soap in due proportion, or the whole may be saponified together. The result is the same, and the choice of methods depends upon convenience in working; but the former is preferable with impure rosin, in order to give it as many changes of leys as possible, and thus to wash out suspended impurities, such as leaves, bits of stick, &c., all of which discolour the product.

Alkali (see Caustic Potash, pp. 251–3, Carbonate of Potash, pp. 253–60, Caustic Soda and Carbonate of Soda, pp. 279–309).—In connection with their application to soap manufacture, it may be mentioned here that all large English soap-makers make their own soda, either from common salt, or from "salt-cake" (sulphate of soda), and causticize at once the liquor formed by the lixiviation of the black-ash. Nearly all the soda used in American and Colonial soaperies is bought in the English market, and imported either as soda-ash or caustic soda. The process of preparing solution of caustic soda or "leys" from soda-ash (or black-ash) is described on p. 307. It is only necessary to add a word of caution to the soap-maker as to the way of dealing with the solution when made. The reason for conducting the operation in so weak a solution as is directed (about 22° Tw., or 1·110 sp. gr.) is, that only under those conditions will carbonate of soda part with its carbonic acid to caustic lime. At higher specific gravities the reaction may even be reversed, and caustic soda will remove carbonic acid from carbonate of lime. It is of the utmost importance to the soap-maker to causticize his leys as completely as possible, *and to keep them so,* since (unless his soap be made entirely from fatty acids, a very rare thing) any carbonate of soda in his leys is simply so much soda wasted. The caustic soda ley should, therefore, only be prepared as it is wanted for use, and when stored should be kept in covered vessels to which air has no access; shallow open tanks should be avoided at all hazards. If, as is frequently the case, stronger ley is required than that produced in the original operation, it should be concentrated by evaporation in open vessels, or by dissolving in it some solid caustic soda. It should be specially noted that for concentrating or storing solution beyond 30° Tw. (sp. gr. 1·150), cast-iron vessels alone should be employed, owing to the solvent action of soda upon wrought-iron.

It may be laid down as an axiom that no ley is sufficiently causticized which liberates bubbles of gas, when a small portion of the clear cold ley has an excess (i. e. more than sufficient to neutralize it and to turn blue litmus red) of mineral acid added to it. This is a sufficiently good test for a foreman to work by.

In the case of nearly pure solutions of caustic soda, a very close approximation to their strength,

i. e. their percentage of caustic soda, may be obtained by the observation of their density or by an hydrometer (Fig. 1, p. 2). These instruments are usually made very cheaply of glass, the lower end being weighted with shot or mercury. When floated, they displace their own weight of liquid, and hence the bulk displaced varies with the sp. gr. of the liquid examined, which is indicated on the stem of the instrument. Two scales are in use among soap-makers, those of Twaddell and of Baumé. The zero point of both is that to which the instrument sinks in distilled water at 15·5° (60° F.). It must not be forgotten that increase of temperature in a fluid, by increasing its bulk, diminishes its sp. gr. All sp. grs. quoted in this article are at 15½° (60° F.).

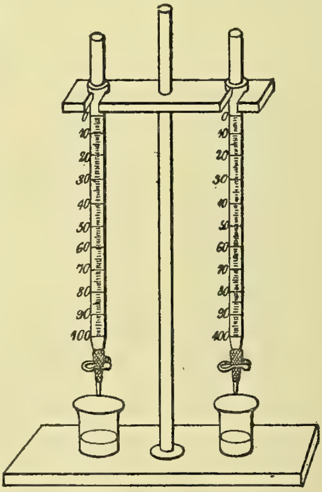
The following table gives the means of comparing degrees Tw. and Baumé with each other and with actual sp. gr.; and also gives the approximate percentages of caustic soda and caustic potash in solutions of that sp. gr. *containing no other salts.*

Degrees Tw.	Degrees Baumé.	Specific Gravity.	Per cent. of Caustic Soda.	Per cent. of Caustic Potash.
5·2	3	1·026	1·81	2·83
7·5	5	1·037	2·72	3·96
11·8	7	1·059	4·23	6·21
14·0	10	1·070	5·44	7·36
19·8	12	1·094	6·65	9·62
23·6	15	1·118	7·86	11·82
26·2	17	1·131	9·07	13·01
32·6	20	1·163	10·88	15·84
42·4	25	1·212	13·90	19·80
53·0	30	1·265	17·52	23·76
64·2	35	1·321	22·97	27·72
78·0	40	1·390	27·50	32·40

It may be noted here that for every 31 parts of pure soda required in any operation, 53 parts of pure dry carbonate of soda, or 143 parts crystals (the soda-crystals or "Scotch soda" of commerce), are required, and that the corresponding quantities of caustic and carbonate of potash necessary to do the same work are respectively 47 and 69 parts by weight. With this basis, a simple proportion sum will show in any given form the quantity of alkali required for any purpose.

It cannot be too strongly impressed upon the young soap-maker, however, that the indications of the hydrometer as regards the alkaline strength of his leys are only reliable in the case of *pure* solutions. When the leys contain much carbonate, sulphate, or other alkaline salts, and especially common salt, as the "half-spent" leys always do, the quantity of alkali must be determined by a more scientific method. This operation consists in ascertaining how much acid of known strength is necessary to neutralize a given quantity of the leys, and is very fully described in books upon volumetric analysis or alkalimetry. It is also referred to in Alkali, pp. 301–2. The apparatus employed is chiefly a burette (Fig. 1237), with pinch-cock to regulate the flow of liquid,—and graduated, usually, into cub. cent. The standard acid solution may be crystallized oxalic acid (63 *grm.* in 1 *litre* or 1000 *cc.*), sulphuric acid, or even nitric acid. If oxalic acid of the above strength be used, every *cc.* corresponds to 0·031 *grm.* of soda. A known weight of the leys (or ash) to be examined is taken in a glass flask, diluted with, or dissolved in, water, a few drops of tincture of litmus added, the whole boiled, and the acid solution added little by little until, after a few seconds' boiling, a permanent faint-red colour is obtained in the solution. The number of *cc.* used is then read off, and the proportion of soda (or potash) is calculated from this. It should be noted that, in this operation, all carbonate, aluminate, silicate, and sulphite of soda (or potash) test as "available alkali." The determination of carbonic acid may be effected in various ways, the principle common to nearly all of them being to expose a known weight of alkali to the action of an excess of acid in a flask, under such conditions that the carbonic acid escapes in a dry state, and the loss in weight indicates its quantity. For further details, as well as for methods of completely analysing leys or solid alkali, works upon analysis should be consulted.

1237.



Lime.—It is very important that the lime used by the soap-boiler should be as pure as possible.

and it is highly desirable to use it when freshly burnt. When this cannot be obtained, it should be kept in well-closed casks, avoiding access of air, which contains carbonic acid, and therefore destroys its power of causticizing alkali. It should contain but little, if any, alumina, magnesia, or silica, and should "slack" readily with water; in fact only what is technically called "fat" lime should be used. Since 28 parts of pure lime are equivalent to 31 parts of pure soda, the quantity of lime necessary for causticizing a given quantity of ash may be calculated, but in manufacturing operations, at least 10 per cent. excess of lime should be used. A clear solution of lime in water may be used for testing the causticity of leys, since any carbonated alkali shows its presence by a cloudy deposit of carbonate of lime.

Water.—The purity of the water employed in the factory is a matter of great moment to the soap-boiler. As a rule, spring-water should be avoided, and river- or lake-water employed whenever possible. If it contains suspended impurities, these should invariably be removed by subsidence or filtration. Organic impurities, if colourless, may be disregarded. The great enemies of the soap-maker are the soluble salts of lime of alkaline earths, and sometimes even of metals, occurring in natural waters, because all these bases form *insoluble soaps* in the soap-copper, and use up large quantities of fat to no purpose, since these insoluble soaps are of no market value themselves, and if disseminated in a marketable soap, injure its appearance greatly. The hardness of water may be determined by "Clark's test," in which an alcoholic solution of pure soap is employed. The amount of soap wasted by hard waters may be ascertained from this table, in which the hardness is supposed to be caused simply by lime salts.

Degree of Hardness.	In 1000 lb. Water.		Soap decomposed by 1000 lb. Water.
	Lime.	Gypsum.	
	lb.	lb.	lb.
5°	0·25	0·61	3·66
10	0·50	1·23	7·31
15	0·76	1·84	11·12
20	1·01	2·45	14·75

If no other than hard water is available, one of the various plans for softening it should be adopted under the guidance of a chemist, such as the addition to the water of milk of lime, either alone or with chloride of barium, or of silicate of soda.

Salt.—As will be seen in the sequel, common salt plays a very important part in soap-boiling, and what has been said with regard to water applies equally to it. The purest kind is rock-salt freed from insoluble matter; next in order comes salt from brine-springs; while sea-salt contains so many other salts besides sodium chloride, especially magnesium chloride, that it should be avoided if possible. When that is not the case, it should be dissolved in water, and the magnesia removed by the addition of silicate of soda, when the insoluble silicate of magnesia should be allowed to subside before the brine is used. In connection with salt, it will be found convenient to remember that strong brine or a saturated solution of salt contains one-fourth its weight or 25 per cent. of sodium chloride, that its sp. gr. is 25° B., and that if nothing else be present in solution, every degree Baumé of sp. gr. corresponds to 1 per cent. of salt.

It will be convenient here to consider a certain physico-chemical property of soaps, of great practical importance to the soap-boiler. The property referred to is the behaviour of soap to various saline solutions, and although not instrumental in the formation of soap, it is almost essential in separating the foreign matters that would otherwise render hard soap impure, and it is also influential in controlling the amount of water in soap. Although soda soaps are soluble in water, they are not soluble in a solution of common salt, nor of caustic soda. If, therefore, common salt be added to a solution of soap (or even of partially saponified fat) in water, the salt dissolves, and turns the soap out from its state of solution, in small flakes which collect together, and float on the surface of the salt solution, by virtue of their less sp. gr. The same thing happens when a strong solution of caustic soda is added to soap in an aqueous solution, or, more gradually when a solution of soap in water containing excess of caustic-soda, or some amount of sodium chloride, is concentrated by the evaporation of its water, as when a soap-copper is boiled by fire or close steam. The addition of salt (or of strong leys), therefore, to soap containing an excess of water, removes the superfluous water, and in chemical language, precipitates the soap from it. Soap so precipitated contains 35–40 per cent. of water. When the fatty matter employed contains coco-nut- or palm-kernel-oils, more salt (or soda-leys) is required for this operation than when those oils are not used.

It may also be noted here that if sodium chloride be added to a potash soap in solution, an interchange of acids and bases takes place, soda soap being formed, and potassium chloride left in the solution. This process has been actually used in Germany for the fabrication of hard soaps.

MANUFACTURE.—Before proceeding to describe this on a large scale, where operations involving considerable mechanical, physical, and chemical knowledge are conducted with a view to produce the best possible article at the lowest cost, a short space will be devoted to instructions for making small quantities of soap of inferior appearance, which will answer well for homely purposes, for the benefit of those living far from large towns, and who may yet have on their farms or stations many of the ingredients necessary for their production.

For those who have plenty of fat or oil at command, but no alkali, the small canisters of pure powdered caustic soda and caustic potash, sold by the Greenbank Alkali Co., St. Helen's, will be found very convenient. With these products, soaps can be made without any boiling. For a hard soap, dissolve 10 lb. of this soda in 4 gal. of water, and allow the leys to cool. Take 75 lb. of clean fat or oil, rendered fluid by heat if necessary, and when it feels just warm to the hand, add the leys to it in an uninterrupted stream, stirring well all the time; continue the stirring for 15 or 20 minutes, and then set aside in a warm place for a day. In this interval, the soda reacts upon the fat, and turns out its glycerine, which remains in the soap. Any impurities in the fat used, or any salt or other extraneous substance, will be apt to spoil the operation. For soft soap, use 20 lb. of this caustic potash, dissolved in 3½ gal. of water, and mix as above with 8¾ gal. of cotton-seed, fish, or other (non-mineral) oil. For a harder soap, one or more of the gallons of oil may be replaced by 10 lb. (or a multiple thereof) of tallow.

A very firm soap may be made on a small scale from the oleic acid from candle-factories, known commercially as oleine or red-oil, by heating it to about 100° (212° F.), and adding thereto one-half its weight of caustic soda leys at 36° B. The combination takes place instantaneously, and it is only necessary to allow the soap to get cold, when it is fit for use. For the preparation of the leys, see p. 1767. They need not be perfectly caustic, but if any carbonate of soda be present, they must be of proportionately higher sp. gr., and the vessels employed must be capacious, in consequence of the effervescence that occurs.

Hard soaps may also be made on a small scale without boiling, by adding to a mixture of 2 parts tallow and 1 part coco-nut-oil, or of 3 parts tallow and 2 parts coco-nut-oil, one-half its weight of caustic soda leys at 36° B., the whole being at a temperature of 55°–60° (130°–140° F.); the mixing, after being well stirred, should be set aside for a day or two. Here also the presence of common salt is a serious obstacle to the combination.

Soaps that require boiling cannot be well prepared in small quantities. Those who wish to make them, however, would do well to study the description of the process on a large scale. In making small quantities of hard soap, it will be well to boil together the fat and the soda leys previously well causticized by lime, and to calculate from the table on p. 1768 how much leys is necessary, taking as a basis that for every 10 lb. of fat, about 1 lb., or rather less, of pure soda (100 per cent.) is required. Combination will not take place unless the solution is quite weak, say 12° B., and when it is effected, salt may be added to separate the excess of water. The salt should be sprinkled in gradually, time being allowed for each portion to dissolve, and when a small sample, taken out on a shovel and allowed to cool, separates into liquor and soap, enough salt is added; the boiling should then be stopped, and the whole allowed to repose; in an hour's time, the soap may be skimmed off. Soft soap is more easily made by boiling on a small scale, since the process is the same whatever quantities of materials are employed. The reader is, therefore, referred to p. 1776 for instructions under this head.

In considering the manufacture of soap in large quantities, the subject may be conveniently and naturally divided under the following heads:—

I. The apparatus and processes employed in effecting the chemical combination between the fatty matter and alkali, including in this a general description of the mode of boiling (or otherwise preparing) soaps of different types.

II. The machinery and mechanical and physical contrivances made use of in converting the chemical compound so produced into a marketable soap.

III. Ingredients and formulæ for the production of special kinds of soaps for particular purposes, including toilet soaps, manufacturers' soaps, &c.

IV. Theory of the action of soap; methods for its analysis and valuation.

V. General considerations of the industry—its location, prospects, legislative condition, &c.

It will be convenient to treat, in the order of their complexity, the somewhat extensive range of subjects included under I., commencing with the simplest, and accordingly we find the following natural sub-divisions:

I *a*. Soaps produced by the direct union of fatty acids and caustic alkali, or by the decomposition of carbonated alkali by fatty acids.

I *b*. Soaps produced by the action of the precise quantity of alkali necessary for saponification upon a neutral fat, without the separation of any waste liquor, the glycerine being retained in the soap. This class includes—*α*. Soaps made by the "cold process," *β*. Soaps made under pressure.

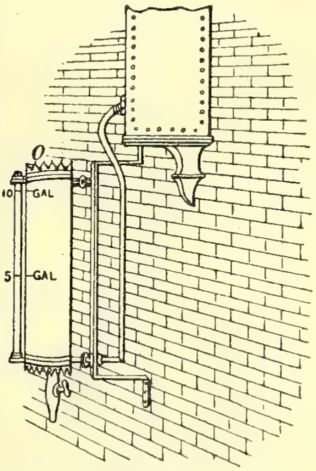
I *c*. Soaps produced by the ordinary methods of boiling in open vessels, working with indefinite quantities of alkaline leys, the processes being controlled by the experience of the operator. These are again subdivided into—α. Soft soaps, in which the glycerine is retained, potash being the base; β. The so-called "hydrated" soaps, in which the glycerine is retained, and of which "marine" soap may be taken as the type; γ. Hard soaps, with soda for a base, in which the glycerine is eliminated, comprising three kinds—curd, mottled, and yellow soaps.

It may be noted that a very large proportion of all the soaps manufactured is included in this last and most complex subdivision, since practical experience shows that, all things being considered, they are the most marketable.

Full directions for the fabrication of these several kinds will now be given, the paragraphs treating of each being numbered to correspond with the above classification.

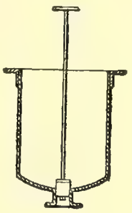
I *a*. In soaps made from fatty acids, the soda is used in the form of a refined carbonated ash at 52° (that prepared by the Jarrow Co., Newcastle-on-Tyne, is recommended), every 100 lb. being dissolved in 160 lb. water in a lead-lined vat, and the solution allowed to settle previous to use. The store-tanks of this, and of the fatty acids employed, are connected with small gauge-tanks or measuring-tubes (Fig. 1238), for the purpose of obtaining uniformity in the results by the use of exact quantities in every operation. For the delivery of the soda solutions into the soap-pan, a special feeder (Fig. 1239) is provided, closed with a movable tampon, by which the flow of liquid may be regulated at discretion; a perforated rose-spout may be advantageously placed under the exit-pipe.

1238.



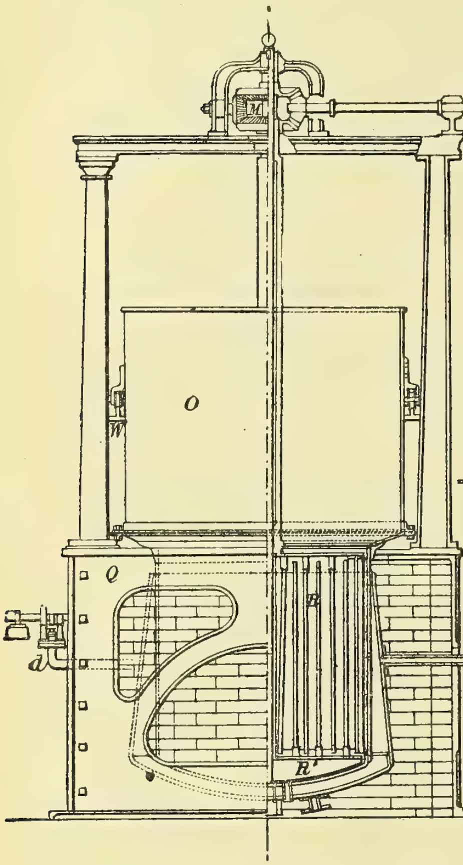
The soap-pan in which the operation is conducted, shown in Figs. 1240–2, is jacketed, the inlet-pipe being at Z, and the steam is either superheated, or used at a pressure of 75–80 lb. Above the pan, is a movable curb O, with slide at *m*, necessary to give room for the intumescence caused by the liberated carbonic acid; a wheel arrangement W enables it to be readily drawn aside on a railway behind the columns N, which support the gearing M. This gearing moves the stirrer R at the rate of 40 rev. a minute; the latter is made of wrought-iron, and is most efficient when the two sets of blades move in opposite directions; when this is not the case, the pan itself should be provided with fixed traverses armed with vertical cross-teeth. In making soap with this apparatus, 1000 lb. oil are run into the pan with the curb O in its place, and heated to 138°–160° (280°–320° F.), according to its quality. At this point, 190 lb. of soda ash for a neutral soap, or 210–225 lb. for a strong soap, dissolved in the proper quantity of water, and at 100° (212° F.), is let into the pan at such a speed that it occupies not less than 6 nor more than 12 minutes. The whole is well stirred meanwhile, and swells up enormously; but 5 minutes after the last portions of alkali have been added, the mass subsides, and, in 15 minutes more, changes from a spongy to a clear, soft, brilliant, homogeneous paste. The curb is then removed, and, in about an hour, 100 lb. of boiling water is let in from the rose-spout of the soda-feeder, and the whole is again well stirred; if it be desired to mix silicate of soda or anything else with the soap, it is added at this stage, after which, the soap is transferred to the cooling-frames (pp. 1781–2), and a fresh batch is proceeded with. Soap thus made has the following composition:—Oleic acid, 65·00; soda, 6·7–7·50; water, 27·50. When rosin is used, it should be added to the oil while the latter is being heated; or the rosin soap may be made in a separate pan, provided with a Morfit's steam-twirl (Fig. 1243), in which the tubular blades of the stirrer are perforated to emit steam while the whole is in motion; 1200 lb. rosin and 2200 lb. caustic leys at 11° B. are boiled together, and the thin jelly so produced is transferred in suitable quantities to other pans. It contains:—Rosin, 54·5; soda, 7·8; water, 37·7. The apparatus described here is also suitable for several other kinds of soap, the steam-twirl, &c., being especially useful for making "hydrated" soaps (p. 1777).

1239.

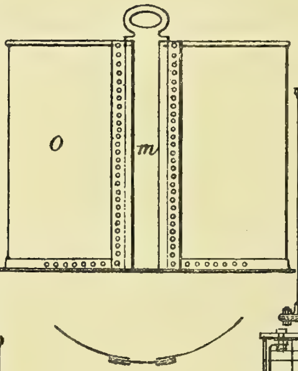


I, *b*, *a*.—The so-called "cold process" consists in mixing given weights of fat, or a mixture of fats, previously melted at as low a temperature as possible, with caustic soda solution of a given sp. gr., the quantities of each being so adjusted that only just enough soda shall be present to completely saponify the fat. After thorough incorporation, the mixture is covered up, and allowed to stand. In a few hours, the chemical reaction commences, accompanied by considerable evolution of heat, and the soap is formed. After the lapse of 2 or 3 days, it is usually hard enough for use. It is obvious that soaps made in this way retain all the glycerine originally combined with the fatty acids, disseminated through the particles of soap. This, and the comparatively low temperature at which the soap is made, are the chief reasons why this process is much in vogue for the cheaper kinds of toilet soap, since the perfumes employed are not dissipated by heat. It is found, however, that soaps thus prepared are very apt to contain an excess of alkali, and hence they are unavailable where perfectly neutral soaps are required.

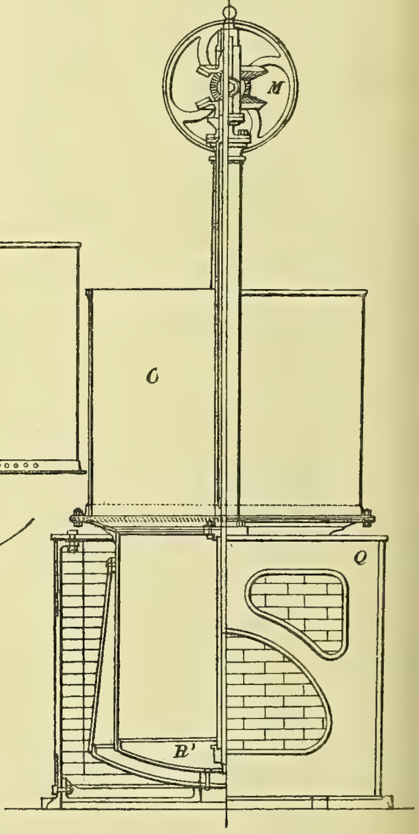
1240.



1242.



1241.



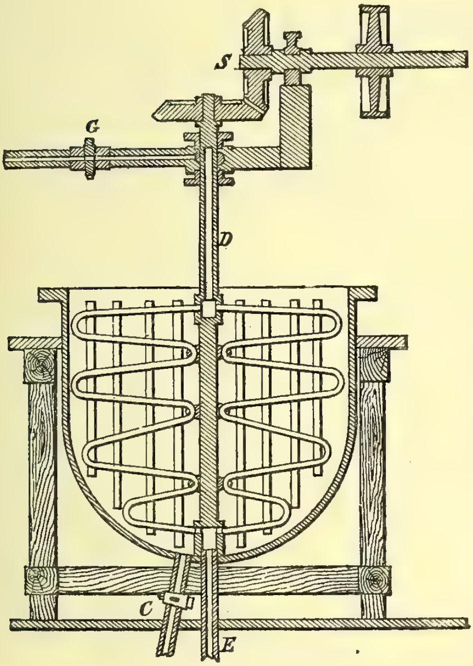
Another objection is, that, as there is no opportunity of removing any extraneous matter, the materials employed must be of the purest, and as the soda leys are usually required in a concentrated (and therefore expensive) form, the process is not so advantageous as at first sight appears. It is chiefly applicable to soaps made on a small scale; when larger quantities are operated on, a mechanical agitator, such as Hawes' boiler, represented in Fig. 1244, is necessary. This, for operating on 2½ tons of tallow, is a cylinder 6 ft. diam., 12 ft. long, with a central shaft provided with radiating arms, set in rotation by any convenient mechanism. Any saponifiable fat or oil may be used, and for every 100 lb. of the pure fat, 50 lb. of caustic leys at 36° B. should be taken. When these are not very pure, i. e. if they contain much extraneous soda salts, especially sodium chloride, saponification will not take place, unless some proportion (10 per cent. on the fat, at least) of coco-nut-oil be used. The following mixtures will be found useful for this process:—

	Tallow.	Lard.	Palm-oil.	Coco-nut-oil.	Rosin.
(1)	100	..	..	..	..
(2)	100	..	..	50	..
(3)	..	..	55	55	100
(4)	50	30	20	..	..
(5)	..	100	..	..	..

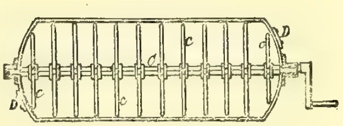
Nos. 1, 2, and 5 make good toilet soaps, which are improved if about $\frac{1}{4}$ of the soda used is replaced by an equivalent quantity of potash. No. 4 with unbleached palm-oil gives a fine yellow soap, liable however to bleach in the light. No. 3 is given on the authority of Cristiani, who recommends the use of 100 lb. leys at 25° B. to the 210 lb. mixed fat and rosin.

The time required increases with the amount of materials operated on at one time. The chief points needing attention are, to use pure materials, to avoid excess of alkali, and so to manage the temperature and the stirring as to make a complete mixture of the melted fat and leys, that will not separate before saponification takes place.

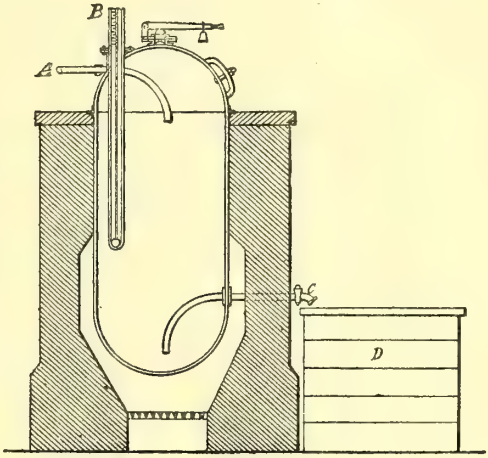
1243.



1244.



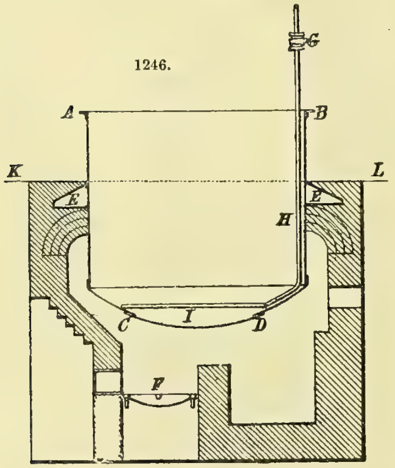
1245.



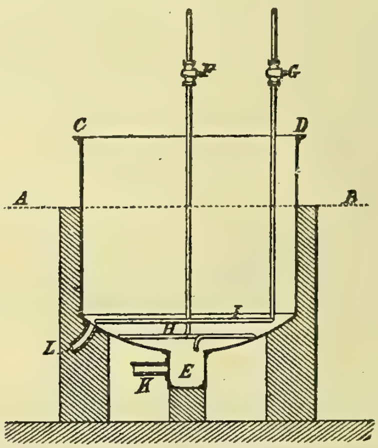
I, *b*, *β*.—In this class, are the soaps produced by boiling under pressure. This process has been the subject of numerous patents at various times, all having for their object the shortening of the time occupied in the ordinary methods of open boiling (I. *c*.), and the saving of the salt employed therein. In this case, also, the quality of alkali employed, whether caustic or carbonate, is accurately adjusted to the fat to be saponified, and the glycerine is retained in the ultimate product; mixtures of any saponifiable fats and resins may be employed. The kind of apparatus used is shown in Fig. 1245; and it consists of a steam boiler provided with a man-hole and safety-valve, with a feed-pipe A and discharge-pipe C, and with a long thermometer B, in a pocket filled with paraffin. The proper quantities of fat and caustic leys are let in through A; all taps are closed; a fire is kindled, and maintained until the thermometer rises to about 154°·4 (310° F.), equivalent to a steam pressure of 63 lb. a sq. in. When it has remained at this point for an hour, the tap at C may be opened, and the contents discharged into a cooling-frame D, by the steam pressure in the boiler. For a good yellow soap, 7 cwt. tallow, 3 cwt. palm-oil, 3 cwt. rosin, and 140–150 gal. caustic soda leys at 21° B. are recommended by the inventor, Dunn. Another formula is 800 lb. tallow, 200 lb. palm-oil, 400 lb. rosin, 175 gal. caustic soda leys at 25° B., for one hour at 122°·2 (252° F.), or 17 lb. steam pressure. It is obvious that this will make a drier soap, since leys at 25° B. contain less water than leys at 21° B., and that the quantity of water desired in this product can thus be regulated to a nicety. In 1865, Bennett and Gibbs, of Buffalo, New York, took out a patent for effecting this operation with carbonated alkali, thus avoiding the expense of causticizing. Their boiler is similar to that shown in Fig. 1245, but is placed horizontally, and provided with an agitator similar to that for Hawes' boiler. The process requires a higher temperature and pressure than the previous one, ranging from 176°·6 to 204°·4 (350°–404° F.), or 220–280 lb. a sq. in. The outlet-pipe is provided with a safety-valve, and the inventors state that if this be loaded to about 250 lb. a sq. in., and the raw materials be pumped in at one end, the process may be made continuous, finished soap coming from the outlet, produced in less than one hour from the introduction of the raw materials. The formula recommended is for every 100 lb. of saponifiable fat, 30–33 lb. of soda-ash of 48 per cent. dissolved in 100 lb. water. In the early stages of the process, the liberated carbonic acid is allowed egress by one of the safety-valves, and if any liquid escapes before a temperature of 163° (325° F.) is reached, it should be returned to the cylinder. The following advantages over ordinary processes are claimed :—(1) Rapidity of manufacture, (2) improvement in quality, (3) increased yield of soap, (4) economy of labour, (5) saving of fuel, (6) use of cheaper fatty material, (7) saponification of the whole of it, (8) uniform certainty of results, (9) retention of glycerine, and improvement of product thereby, (10) ability to use carbonated alkali. It is obvious, however, that the risk of explosion is not slight, and the practical difficulty of working the agitator at that temperature and pressure must be considerable.

I, *c*, *a*. *Soft Soaps*.—The production of these is the simplest case of the process most usually adopted in the fabrication of soap, viz. boiling in open vessels, technically termed "coppers," with the aid of steam (either wet or superheated) or of fire, or of the two simultaneously. It will be convenient, therefore, to describe here the construction and fittings of the various kinds of soap-coppers (or soap-pans), and the different modes in which steam and fire are applied to boil their contents.

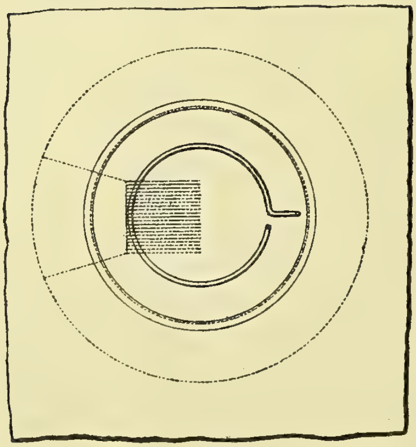
In the days when there was an excise duty upon soap, "coppers" were usually of what is now considered a very small size, and were constructed of cast iron; they consisted of hemispherical pans, upon which were mounted as many cylindrical rings as were necessary to make the copper of a suitable depth, usually about twice its diameter; the rings were joined to each other, and to the hemispherical bottom, with cement joints. There was no limit to their size, except the difficulty of making large castings, and they were usually encased in masonry, and fitted with fire-places and flues in the manner to be presently described for modern wrought-iron "coppers." In the case of



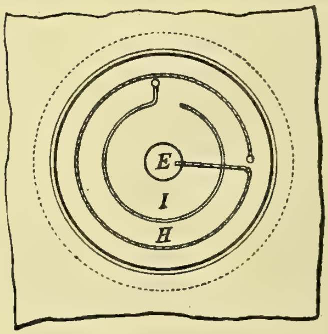
1246.



1248.



1247.



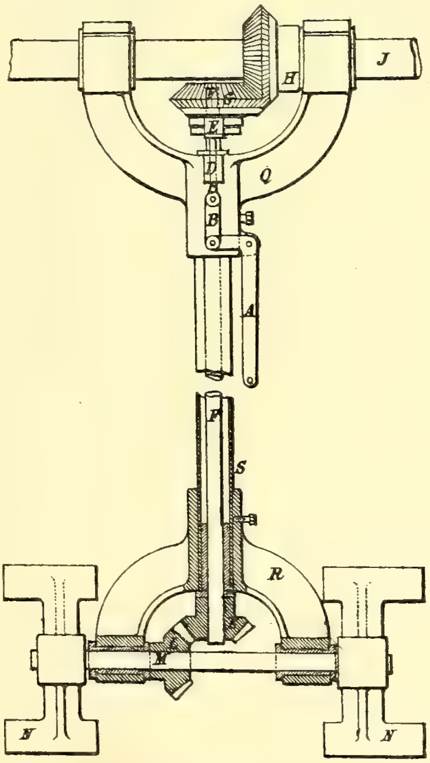
1249.

those boiled by fire (the only method until steam-boiling was introduced), the hemispherical bottoms were very apt to crack from overheating, and from many other causes, which it is scarcely necessary to detail, as these pans are fast becoming obsolete.

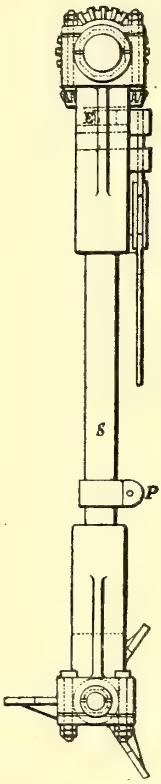
The removal of the excise duty in England, in 1853, gave an enormous impetus to the soap industry. Manufacturers were no longer deterred from making large batches of soap by the fear that, if they were spoiled, double duty would have to be paid when they were re-made and produced fit for sale; and, as a natural consequence, numerous experiments were tried, both with the raw materials and the apparatus employed. Soap-coppers are now made of colossal size, those capable of turning out 50 tons of finished soap (112,000 lb.) at one operation being by no means uncommon, and some of the large American manufacturers have built even still larger coppers, requiring a building of 3 stories to contain them. Although it is desirable that those boiled by fire should be circular in shape, and not too large—say 20 tons capacity—the coppers whose contents are boiled by steam may be of any desired shape, circular, oval, or rectangular, provided that the steam-pipes be carried into the corners (if any), and be so arranged as to ensure uniformity of ebullition throughout the whole mass. There is no necessary proportion between diameter (or superficial area) and depth ; English soap-makers are more accustomed to pans whose diameter is to their depth as 1 to 1, 1 to 1·25, or 1 to 1·5 (e. g. a pan 15 ft. diam. and 15 ft. deep will turn out 25–30 tons of soap); while their American confrères, less trammelled by tradition, increase the ratio as far as 1 to 2, 1 to 2·5, or even 1 to 3.

Soap-coppers are now almost invariably built of wrought-iron plates, and rivetted together in the place where they are eventually to stand. Figs. 1246, 1247 show a simple form of copper for fire-boiling, with the fire-place, flues, &c.; A B D C is the outline of the copper, C D being a circular renewable plate, in the part most exposed to the action of the fire F. At E, are supporting lugs of cast-iron; K L is the floor-level; H I, a steam-pipe ending in a perforated coil, steam being controlled by the cock at G. Figs. 1248, 1249 show a copper where steam only is used: A B is the floor line; C D E, the copper, provided with a "hat" at E to receive impurities that subside, and to enable spent leys to be removed completely by the draw-off at K. Another draw-off is fitted at L. Two steam-worms are provided, H, with cock F, whose coil is perforated, admitting "open" or "wet" steam among the copper contents, and I, with cock G, in which high pressure or superheated steam is circulated, for use when it is desired to evaporate water. This last coil is usually omitted in the largest coppers, being only used in making curd and mottled soaps.

1250.



1251.



An important adjunct to a soap-copper is a little piece of machinery for preventing the contents from boiling over, as they are apt to do when saponification is taking place, and also in a later stage, even after the steam is turned off. It is called a fan, and is represented in Figs. 1250, 1251; it consists essentially of a rotating paddle, whose blades just touch the top of the boiling mass. The motion is derived from an overhead shaft J, on which is keyed a bevel-wheel H, gearing into a similar wheel G; this latter slides on a feather on the shaft F, being thrown in or out of gear by a fork E, to which is attached a rod C, actuated by links B and bell-crank A, in the bottom end of which is an eye for attaching a cord which may be drawn to right or left. The lower end of the fan-shaft drives the over-shaft M, on which the fans N are keyed by means of bevel-wheels K L. The top and bottom of the fan-shaft are carried by bushes driven in at each end of a piece of stout 2-in. steam-pipe, and the pipe S is inserted in cast-iron frames Q R. Near the lower end of the pipe, is a shackle P, to which a rope or chain is attached for lowering or raising the fan, according to the surface of liquid in the copper. The whole swings on the axis of shaft J.

The fabrication of soft soaps will now be described. Soft soap is a more or less impure solution of potash soap mixed with glycerine in caustic-leys, and forming at ordinary temperatures a transparent smeary jelly, containing at times, and especially in cold weather, white grains, which are impure stearates of soda or potash. The most suitable form of copper for making it is shown in Fig. 1246. In England, whale-, seal-, and linseed-oils are chiefly used, and occasionally a little tallow to produce the grains, or "figging," just described, an appearance which serves no really useful purpose. On the European continent, hempseed-, linseed-, camelina-, and poppy-oils are used, and also rapeseed- and train-oils, especially in summer, since they produce a harder soap. In America, cotton-seed-oil, and oleic acid, are often employed. Hempseed-oil gives a greenish tint much prized by consumers, which may be imitated by the addition of a little indigo precipitated by potash from its solution in sulphuric acid.

A very desirable, but not necessary, adjunct to the soap-copper is a set of tanks of iron or wood, whose contents per inch of depth are known, in order that the quantities of oil and leys let into the copper may be regulated. In many large factories, the practice is to keep a strict account of the quantity of fatty matter and rosin used, but to control the amount of leys according to the judgment of the soap-boiler. Such gauge- and store-tanks may be in any convenient place, and pipes or open shutes carried from them to deliver their contents into the copper; suitable plugs and cocks control the flow of the liquid at the pleasure of the operator.

To make an unsophisticated soft soap, a suitable quantity of oil is run into the copper, not exceeding ¼ its total capacity; at the same time, potash leys at 9°–11° B., not absolutely caustic, but retaining some potassium carbonate, are let in, and the steam is turned on, or the fire kindled, or both; the fan may also be adjusted at the height beyond which the soap is not to boil, and the whole is carefully watched. If the copper has not boiled until a volume of leys has run in equal to that of the fat, the stream of leys should be stopped, and started again when the ebullition commences. If the oil and leys do not appear to have combined, the fire should be checked, the stream of leys stopped, and gentle steam-boiling continued until this is the case. It is very difficult, especially with rape-oil, to get the alkali to combine, but when once the process has begun, it goes on with tolerable rapidity with subsequent additions of leys. From time to time, small samples of the soap are dropped upon a glass plate, and after cooling at a temperature as near 8° (46°·4 F.) as can be obtained, are carefully examined. The soap is good if it is clear and translucent; a fatty border indicates deficiency of alkali; while if the sample be granular, grey, and lustreless, too much ley has been added, a fault that must be corrected by the addition of more oil, previously mixed with leys at 2° B. Should the sample separate on the glass into soap and clear liquor, the quantity of leys is excessive. If the combination be good, and alkali deficient, stronger ley (at first 15°–16°., then 23°–25° B.) may be cautiously added; a sign of saturation, or rather slight excess of alkali, is the appearance of a striped skin, or ley-veins, on the surface of the sample. When it is judged that enough alkali is present, the steam is turned off, and a certain amount of water is evaporated by boiling the copper with fire, during which operation the bubbles get larger, the soap being almost laminated, and make so much noise in their escape that the boiler's phrase is "the soap talks."

When finished, a small sample must not glide or be slippery on the glass, nor must it draw into threads when worked up between the fingers and thumb; a very small ring should appear in the sample in 12–15 min., indicating the necessary slight excess of potash. The soap is filled into barrels while quite hot, and to promote rapid cooling of the mass, cold soap is often added.

A somewhat shorter method, saving the evaporation in the later stages, has been introduced of late. For every 100 lb. oil, 200 lb. leys at 20° B. are required; when liquid fats are used, this quantity is run in at the commencement of the operation; with solid fats, ½ may be taken, and when thoroughly incorporated, the rest may be added, and the soap boiled as previously described.

If it be desired to make a soft-soap in which some of the potash is replaced by soda, the proportions of the two leys must be accurately adjusted to each other, and to that of the fat used. The process was first worked out by Gentele, and improved by Cristiani, who recommends for the saponification of oil by ⅗ potash and ⅖ soda the following formula:—5000 lb. oil, 2674 lb. potash ley at 20 B., 740 lb. potash ley at 25° B., and 2353 lb. soda ley at 20° B. If enough steam be not condensed in the boiling, water may be added to make the whole weigh 12,500 lb.

To produce a grained soft-soap (or "fig"), it is essential to use pure potash leys, and to employ some hard fat, the stearic or palmitic acids of which form potash salts whose crystallization produces the grains, within somewhat narrow limits of temperature, viz. 9° (48°·2 F.) and 15°

(50° F.). The following fat mixtures will produce it:—(*a*) 55 palm-oil, 45 oleic acid; (*b*) 55 palm-oil, 15 tallow, 30 linseed-oil; (*c*) 70 palm-oil, 30 linseed-oil. An artificial grain is given by clay starch, &c.

Two kinds of genuine soft-soaps occur in commerce, whose composition is:—

	I.	II.
	per cent.	per cent.
Water	50·5	31·5
Potash	9·5	11·5
Fatty acids	40·0	50·0

The question of admixtures with genuine soft-soap, after its fabrication has been completed, is one that demands the serious attention of both manufacturer and consumer. They may be divided into two classes: (1) those intended to increase the detersive power; and (2) those added solely to cheapen the product. To the latter, belong clay, starch, fecula, glue, and a number of other fraudulent admixtures, whose detection will be dealt with under the head of soap-analysis. The first class demands a few explanatory words, and contains chiefly two substances, rosin, and silicate of soda or potash; the manufacture of the latter, and their use in hard soaps, are described on pp. 1786–7. For soft-soap intended for household and laundry purposes, rosin may be substituted for part of the saponifiable material (to the extent of 10–15 per cent. upon the total oil used) without injury, and, in some cases, with actual benefit; in the same class of soaps, the addition of silicate (or carbonate) of potash or soda certainly increases the detersive power, especially where hard water is employed. Most of the soft-soaps made, however, are used by woollen manufacturers, for wool-washing, fulling, scouring, and sizing, and there is no doubt that the best soap for these purposes is a *genuine potash-oil-soap*. Experience has shown that the addition of rosin has an undesirable effect upon the fibre, and that the presence of soda in any form is absolutely injurious to it. Wool in its natural state is lubricated by "suint," which contains nearly 50 per cent. carbonate of potash, and scarcely a trace of soda; it is evident therefore that in discarding soda, and using potash, the manufacturer follows the teachings of nature. The use of silicate of potash is injurious, since it attacks the fibre of the wool, and in some cases by its decomposition, even deposits silica therein, greatly to the detriment of the ultimate fabric. So much injury has been done by the use of unsuitable soaps, that many woollen manufacturers have been driven to make their own, thereby, as they think, ensuring purity. This, however, is also a hazardous proceeding, and it would be really more to their interest to state their exact wants, and to pay a proper and fair price for a soap carefully made with all the appliances and knowledge of a large soap-factory, than to run the risk of using a product in which, from want of practice or knowledge, a serious oversight had occurred. The excessive desire for cheapness on the part of purchasers has done more than anything else to depreciate the quality of soft-soaps (and of others). Further general remarks on this subject, and upon the desirability of purchasers buying soaps whose composition is guaranteed by analysis, will be found on pp. 1793–4.

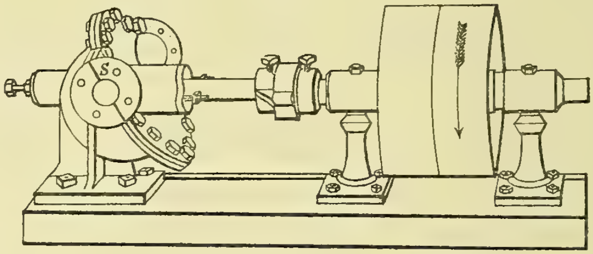
I, *c*, *β*.—The method of making "hydrated" soaps is very similar to that just described. Fatty matter and (soda) leys are run into the copper, and the whole is boiled together, care being taken to avoid an excess of alkali at first; when saponification has taken place, leys are cautiously added until the soap tastes very faintly of caustic alkali, when the operation is finished, and the soap is ready to be transferred to the frames. Marine soap, for use with sea-water, is made in this way, the fatty matter being entirely coco-nut-oil, and the leys being usually at 20° B. This soap is soluble in weak brine, which other soaps are not (p. 1769). It is difficult to make the saponification begin, but once begun, it proceeds with extraordinary rapidity, the united mass of oil and leys swelling up almost instantaneously to many times its volume. In connection with hydrated soaps, Blake and Maxwell give the following table for the quantity of soda leys necessary for their manufacture:—

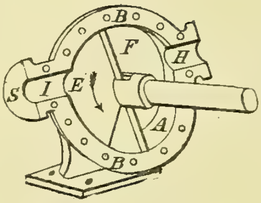
100 lb.	tallow	require	3800°	at	11° B.
„	coco-nut-oil	„	4100°	„	16°–20° B.
„	palm-oil	„	3200°	„	18°–22° B.
„	lard	„	3400°	„	13° B.
„	tallow oleine	„	2800°	„	18°–22° B.
„	olive-oil	„	3000°	„	16° B.

To use this table, divide the larger number of degrees by the smaller, and the quotient is the number of lb. of soda leys at the gravity of the divisor, required to make a hydrated soap with 100 lb. fat.

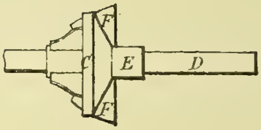
I, *c*, *γ*.—*Hard soaps*, with soda for a base, made by open-pan boiling, in which the glycerine is eliminated. This class probably includes 90 per cent. of the total soap made in English-speaking countries, and may be divided into three kinds, curd, mottled, and yellow. The coppers for their production have already been sufficiently described, but a necessary and hitherto unused adjunct must now be explained, viz. the pumps required for changing the leys beneath the soap. They may be placed inside the copper, or outside, and, in this latter case, are connected with the outlet pipes at K L, Fig. 1248. For small pans, a simple hand suction-pump answers; for larger ones, a single- or double-acting lift- or force-pump may be placed inside the copper, and worked by hand, or by an eccentric on a shaft. In large soap factories, some form of centrifugal pump will be found very useful; the usual objection to the use of these pumps, viz. the need of constant lubrication, being obviated by the fact that, so employed, they lubricate themselves. Their great advantages are the absence of valves and of easily deranged working parts, and the large amount of work they will do in a short time. In England, the names of Gwynne and Appold have long been connected with centrifugal pumps; in America, the one most usually employed is Hersey's patent rotary soap-pump (Hersey Bros., Boston, Mass.), which is represented in Figs. 1252, 1253, and 1254. The pump should be placed as little as possible above the outlets in the coppers, and connected therewith by 2½-in. iron pipes, provided with valves. The pipes inside the copper, communicating with the outlets, have swing joints, so that they can be raised or lowered at pleasure. To avoid the pipe-system becoming choked by soap congealing in it, a steam-pipe should be inserted at one end, to warm the pipes and pump previous to use, and to "blow-out" all their contents at the end of the operation. In the figures, S is the suction-pipe; H, the delivery; F, the blades set upon a cone (the rotation of which in the closed case produces the pumping), which is kept in its place by adjustable set-screws. This pump will transfer to any desired part of the factory, leys, melted fat, finished soap (if not too stiff), "nigre," and soft curd. The diameter of the pump is 10 in., of its outlet 2½ in.; when making 120 rev. a minute, it will pump 6000 gal. an hour, its contents being twice emptied in each revolution.

1252.





1253.



1254.

Whatever kind of hard soap is to be made, the first stages of the process are the same for all; but since a curd or a mottled soap requires the use of fire or "close" steam to evaporate water during the final stages, it is desirable to commence making those in coppers so provided, and either high-pressure or superheated steam may be used in the close-steam worm. Yellow soaps may be made in coppers furnished only with an "open" or "free" steam worm. A useful addition to any copper, giving more room to boil, and hence adding to its capacity, is a "curb," or ring 2–3 ft. high loosely fitted on in segments above the angle-iron of the top ring of the copper itself, and capable of easy removal. If, as in Fig. 1248, the copper project 2½ ft. above the floor, a "curb" 2¼–3 ft. high may be conveniently added, and the fan adjusted so that its blades revolve about 1 ft. below the top of the curb.

To commence a boiling of hard soap, melted fat and caustic soda leys (hereafter only called leys) at about 11° B. are simultaneously run into the copper, and the steam is turned on; the same precautions to prevent an excess of leys must be observed as are detailed in making soft soap (p. 1776); if leys stronger than 12° B. be used at this early stage, saponification will not take place. When the contents of the copper present the appearance of a homogeneous magma or paste, leys of a higher sp. gr., say up to 25° B., may be cautiously added, but it is not essential to do so. The boiling, and the addition of fat and leys, must be continued until a small sample cooled between the fingers has a tolerably firm consistence, and when applied to the tongue, no caustic taste, or only a *very* faint one. Should there be a strong taste (or "touch," to use the American term), or should the sample separate into soap and liquor when squeezed, too much ley has been admitted, and more fat must be added. Should the sample be soft and greasy, more leys are required, especially if any unsaponified fat be visible; occasionally the two conditions obtain, both caustic liquor and fat appearing in a sample, which is evidence that combination has not taken place; the remedy is more boiling, with occasionally the addition of water. Practice alone will enable the operator to judge of the completion of this first operation, called "pasting" (French, *empâtage*). In English phraseology, it is called "killing the goods" or raw material, and the soap is then said to be "close" or in a "hitch" or "glue." In this condition, the soap should contain about $\frac{9}{10}$ of the total soda necessary for complete saponification, with a large excess of water, which is separated from it by the next operation.

Separation (French, *relargage*).—To effect this, a quantity of common salt is sprinkled into the copper while still boiling, or the strongest brine (24° B.) is run in. Since the quantity necessary depends entirely on (1) the sp. gr. of leys used in the last operation, (2) the amount of condensed water where free steam is used for boiling, and (3) whether there is much coco-nut- or palm-kernel-oil in the fat employed (p. 1769), no directions can be given as to how much salt should be added; the addition should be made cautiously and gradually (taking care to allow time for the solution of the salt), and continued until a small sample removed upon a spatula or trowel allows *clear* liquor to run from it. During this operation of "graining," the contents of the copper are very apt to boil unsteadily, and occasionally to boil over with great violence. When this point is reached, the whole process should be stopped, and, the steam being turned off, the copper should stand at least 2–3 hours. Its contents then divide themselves into two portions, the upper consisting of soap-paste holding about 40 per cent. water, and the lower of a solution known as "spent leys," containing common salt, any carbonate and other soda salts present in the original leys as impurities, and nearly all the glycerine of the fat employed (see p. 1800). It should contain *no caustic soda*, and *no soap* or saponifiable material; if it contains the latter, enough salt has not been used. For the presence of caustic soda, a sensitive tongue will be found a sufficiently delicate test, while the addition of a mineral acid will throw up a scum of fatty matter, if any be present; it will also be found useful to observe the sp. gr. of the spent leys, as a means of controlling the amount of salt used. After the copper has stood for some hours, the spent leys should be pumped off, and, if there is then sufficient room, more fat may be run in, and the whole operation repeated; at this stage, the rosin is usually added for a yellow-soap, being broken into lumps, and shovelled in, unless it is combined with soda in a separate copper, and mixed with the fat-soap on the next operation.

Clear-boiling (French, *coction*).—All the goods having been "killed," and the spent leys removed, a small charge of leys at about 12°–14° B. is run in, and the copper boiled for 2–3 hours; at the end of this operation, the soap should have a faint but decided caustic taste, and a small sample on a spatula should allow clear leys to run off it; if this be not the case, more, and in some cases stronger leys, must be added. This operation communicates additional soda to the soap, and washes out, as it were, some of the salt entangled in it. After some hours' subsidence, the "half-spent" leys that sink to the bottom are pumped off, and may be used in another copper for "killing" more fresh goods; the soap from such leys, however, will be of an inferior colour.

The next stage of this operation is to boil the copper with open steam; if the contents are not perfectly homogeneous, and in a state resembling a stiff paste, i. e. if the copper be not "close," but have a tendency to separate into leys and soap, when examined on a spatula, the sp. gr. of the entangled leys is reduced by the addition of water, until the desired condition is reached. A small stream of leys at about 12° B. is then allowed to trickle in, until the homogeneous paste again separates into flakes of soap and clear leys, boiling being continued all the time; the soap should now taste strongly of caustic soda, and feel hard when cold; this operation is technically called "making" the soap, and when enough leys have been run in, boiling should be continued for some hours, to ensure complete saponification, since it is difficult to make neutral fats take up the last portions of soda. The large coppers previously alluded to require a whole day (12 hours) for this operation.

The operations above described, may *in experienced hands* be somewhat reduced in number and time, but much greater care is then required. By the proper use of leys of various strengths, and of salt, it is possible to "kill" 40–50 tons of mixed tallow and rosin in one copper in a day—to dispense with the next operation—and to "make" the copper on the day following, finishing it on the third day. The mode of finishing depends entirely on the kind of soap required.

Curd Soaps.—The raw materials for curd soaps should contain no rosin, and but little, if any, coco-nut- or palm-kernel-oil, but any other oils or fats may be used. White curd is usually made from tallow or lard, or a mixture thereof; brown curd, from bleached palm-oil, or kitchen-grease, or bone-tallow; and manufacturers' curd-soaps, from various fats. When the soap is "made," the open steam is shut off, and the boiling is continued either with fire or with close-steam; this concentrates the leys, and the flakes of soap gradually approach the spherical form. From time to time, the boiling is stopped, the sp. gr. of the leys is observed, and a sample of the soap, from which the leys have been allowed to separate, is put out to cool. When it is sufficiently hard, the boiling is finally stopped, and after a few hours' subsidence, the soap is ready to be removed; the amount of water left in it varies inversely as the sp. gr. of the leys in which it is boiled.

Mottled Soaps.—The term is here used to denote the old-fashioned curd-mottled soaps, not those marbled with blue, grey, or red, which have appeared in the English and foreign markets within the last 20 years, and which are described on p. 1787. In the fabrication of soap, it is impossible to avoid entirely the presence of earths and metallic oxides. These consequently decompose a small portion of the soap, combining with its fatty acids, and forming soaps of lime, magnesia, and iron (from the "coppers"), which are insoluble, but softened by heat, and disseminated in a state of minute division through the soap-paste; any slight impurities in the fat employed, when not dissolved in the caustic soda solution, are similarly diffused. If, after a soap is "made," the leys in which it is suspended are concentrated to a point short of that necessary to produce hard curd-soap, and it is then transferred to the cooling-frames, with a certain quantity of leys entangled in it, these insoluble particles will, during the solidification of the soap, collect together, and produce the appearance known as "mottling." No rule can be given for the point of concentration; it varies with the fat used, with the amount of leys in the copper, with the quantity of salts other than caustic soda in them; and in short, the proper "mottling condition" is a physical one, chemical tests being of no use in deciding it. Nothing but practice and careful observation can make a successful mottled-soap boiler. The principle of the process has been clearly laid down, and the various formulæ given in books, involving in many instances several changes of leys, are but different modes of arriving at the same result, viz. the suspension of pure soap, and of soaps of the metallic oxides, in soda leys of a given sp. gr. If the soap be boiled too long, it "sets" in cooling before the mottling has had time to aggregate; if it is not boiled enough, an undue quantity of leys remain in the soap; but, from their mode of manufacture, mottled-soaps always must contain some leys in the cavities between the curds; hence they are the most suitable and really economical soaps for hard waters. It not unfrequently happens that the copper does not contain enough metallic soaps, &c., to produce a definite mottle. In this case, some "mottling" is added; for a grey, Frankfort-black, or very finely levigated black oxide of manganese, may be used; the peculiar greenish mottle which becomes red on exposure, characteristic of Marseilles and Castille soaps, is produced by adding some solution of protosulphate of iron to the copper when it is nearly finished (about 4 oz. of the salt to 100 lb. fat); the precipitated protoxide of iron suspended in the soap is greenish, but becomes peroxide in contact with air, to which the change to a red colour on exposure is due.

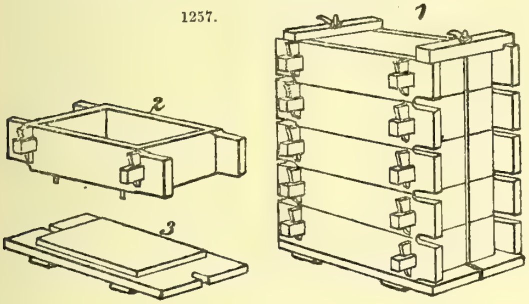
In England, mottled soaps are usually made from kitchen-grease and from bleached palm-oil. In Marseilles, from mixtures of various seed-oils, of which olive-oil is the principal, and cotton-seed-, poppy-, hempseed-, gingelly-, and ground-nut-oils are frequent components. In these mottled soaps, little or no coco-nut- or palm-kernel-oil should be used, although such oils form an almost essential constituent of the new mottled soaps referred to above.

Yellow Soaps.—The finishing operation for these is termed "fitting" in England, and *liquidation* in France, and requires considerable judgment on the part of the operator. After being thoroughly well "made," the copper stands at rest for at least 12 hours; the half-spent leys are then pumped off, and the open steam is turned on. When the copper is again boiling, it should be continued so until its contents are perfectly homogeneous (the time depending much on the size of the copper), and the soap should then be examined with a clean trowel. When in proper condition, a thin layer should drop off a *hot* trowel held edgeways, in two or three flakes, leaving the metallic surface quite clean; but if, as is more probable, the layer breaks up into several small flakes, and the soap is stiff, water should be cautiously added, to reduce the sp. gr. of the still-entangled leys. If, on the other hand, the film will not leave the trowel at all, a small quantity of strong leys (say 15°–20° B.), or of brine, may be cautiously added, to cause it to do so. In the first case, the "fit" is said to be "open" or "coarse"; and in the second, to be "close" or "fine." Here, again, practice and observation alone enable the operator to obtain "a good fit," and when it is obtained, the steam is turned off, and the whole is allowed to stand. The copper is then covered up with planks, or an iron cover, and kept as warm as possible; small coppers may stand a day or two, large ones as long as a week. During this period, the contents arrange themselves in three layers, (1) a light crust full of air bubbles, technically called "fob," (2) the finished or "neat" soap, forming about $\frac{4}{5}$ of the whole, (3) the "nigre," which is an impure solution of soap in leys, and contains all the impurities present in the copper. The size of this last depends entirely upon the character of the "fit." A fine fit gives a very large nigre, containing much soap; while a coarse fit gives a small nigre, composed chiefly of impure leys. The English practice is to fit rather "fine," competition among the various makers for purity and colour being excessive; while the Americans are usually content with a coarse fit.

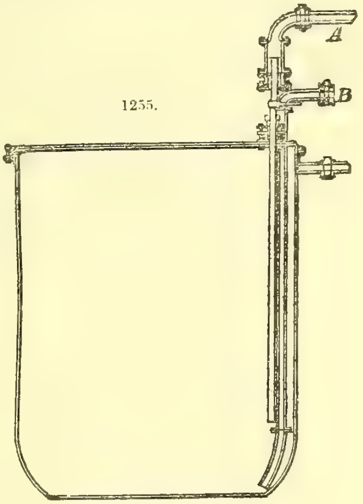
The finest yellow soaps are made from the best tallow and rosin, which last is an essential constituent of them; in some cases, lard, or lard-stearine, is used. Inferior qualities may be made from the nigres of better sorts, from bleached palm-oil, greases of all kinds, and in fact any saponifiable solid fat; fluid oils must be used, if at all, in small quantities and with caution. The proportion of rosin may vary from $\frac{1}{6}$–$\frac{1}{5}$ of the total fat, to an equal weight, or even more, according to the quality of soap required. In England, the very best quality is known in the trade as "primrose," and is made from the finest (unbleached) tallow and "window-glass" rosin; the lowest grade of brown from the nigres of the grades above, mixed with curriers' grease, leather tallow ("sod-oils"), and other dark and foul but hard fats, with black rosin.

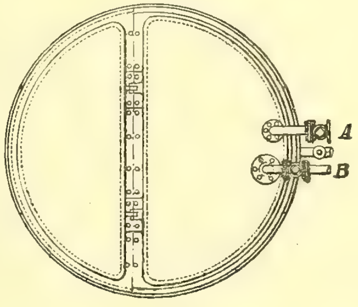
The soap having been finished in the copper, the next stage is to transfer it to the cooling-boxes, or "frames," as they are usually called. Curd soaps should always be carefully skimmed off the leys by ladles, since they are too stiff to pump, and most mottled soaps are in this condition also; if, however, much leys be entangled in them, and the curd be flat, they may be pumped out. In large factories, fitted soaps are invariably transferred to the frames by suitable pumping machinery. A peculiar method of emptying coppers that contain perfectly homogeneous soaps, without any nigre or leys beneath them, was invented by Gossage, and is represented in Figs. 1255–6.

1257.



1255.





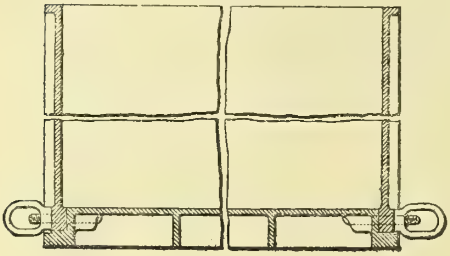
1256.

An air-tight cover is screwed on to the copper, and a blast of air is turned in through A; the pressure thus exerted forces the soap out through the delivery-pipe B in a continuous stream, until the lower end of that pipe becomes uncovered, when air rushes through it. This is chiefly used for the "blue-mottled" soaps, described on pp. 1787–8.

Soap-frames are of two kinds, according as it is desired to cool the soap slowly or quickly. In England, the internal measure of both is 45 in. × 15 in., a relic of the days when a duty (removed in 1853) was levied; the width of this makes the length of the English bar of hard soap. Where slow cooling is required, as is always the case with mottled soap, wooden frames, usually made of pine, are always employed. Their general appearance is shown in Fig. 1257; each section or "lift" (2) is lined with thin sheet-iron, the wood being 2½–3 in. thick, and the several sections, each about 9–12 in. deep, should fit closely upon each other when piled in a series (1). The bottom of the frame (3) may be made of wood or of brick; in the case of curd-mottled soaps, it is convenient to have a well in the bottom, to receive the leys which drain from the soap, especially if, as is frequently the case, the frame is 20–30 ft. high. Most curd and all yellow soaps are cooled rapidly in cast-iron frames of any desired shape and size. Figs. 1258–9 show a longitudinal section and plan of a form frequently adopted in England, which is almost water-tight; the superficial measure is 45 in. × 15 in., and the height 50–60 in. The four sides are held together by bolts and nuts, and when the soap is cold (i. e. after the lapse of 3–7 days for this size), these are unscrewed, the sides are removed, and a solid block of soap is left standing on the bottom of the frame. This may be at once cut up into slabs and bars, or may be slid away bodily to store. Occasionally such frames are mounted upon wheels, for convenience of transport about the factory.

When it is desired to cut the soap, the sides of the block are marked with a scribe, Fig. 1260, the teeth of which are set at the thickness desired for the bar of soap. A brass or steel wire is then taken by two men, and drawn through the block, Fig. 1261, which is thus divided into slabs; these are at once removed to a machine which will divide them into bars. The cutting-machine usually employed in England is shown in Figs. 1262–4. The cutter itself is worked by a lever-frame L, which contains wires, or, for very hard soaps, thin steel knives *k*; the slab is placed longitudinally and nearly upright on the base-board *b*, and the lever-frame is then drawn through it.

The bars thus formed fall back upon the shelf *f* behind, whence they may be removed and set aside to get cold. Before repeating the operation, the lever-frame must be raised and hitched in its place by the spring-catch *c*. The bars, when removed from the machine, are piled across each other in "open pile," in such a way that air freely circulates among them. When thoroughly set, they are stored away in "close pile," or packed. In America, Ralston's cutter and spreader, Fig. 1265, is largely used; it has an arrangement A B for spreading and stamping the bars, and is very useful where soap is rather soft when freshly cut. The slab is laid upon C, and the cutting-wires are shown at D. Van Haagen, of Cincinnati, has devised a machine for dividing a frame of soap into bars all at one operation, and various slabbing-machines have been invented, none of which, however, has come into very general use, and they will not be further described.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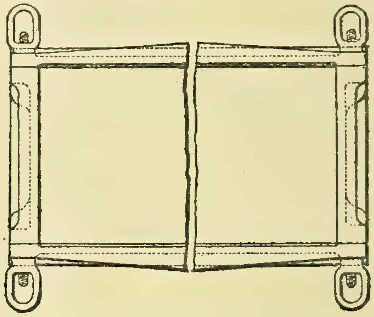
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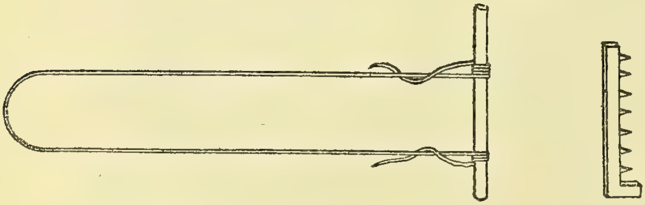
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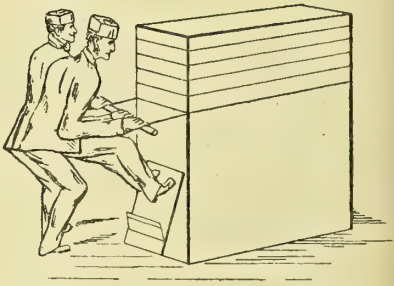
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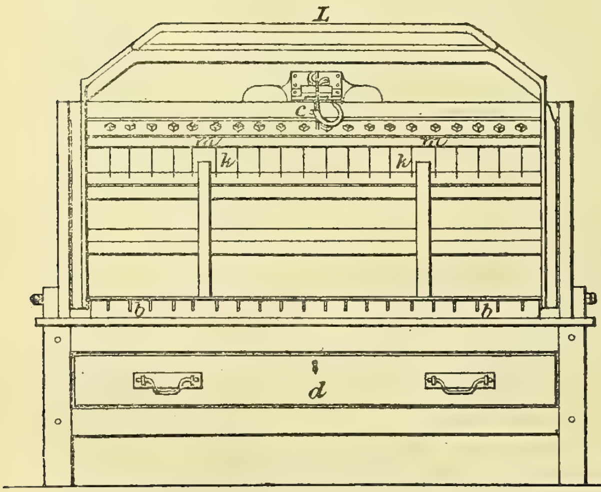
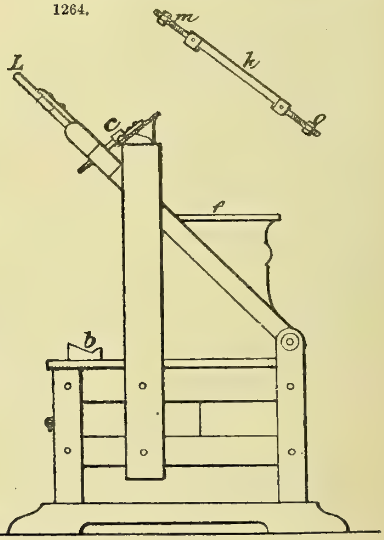
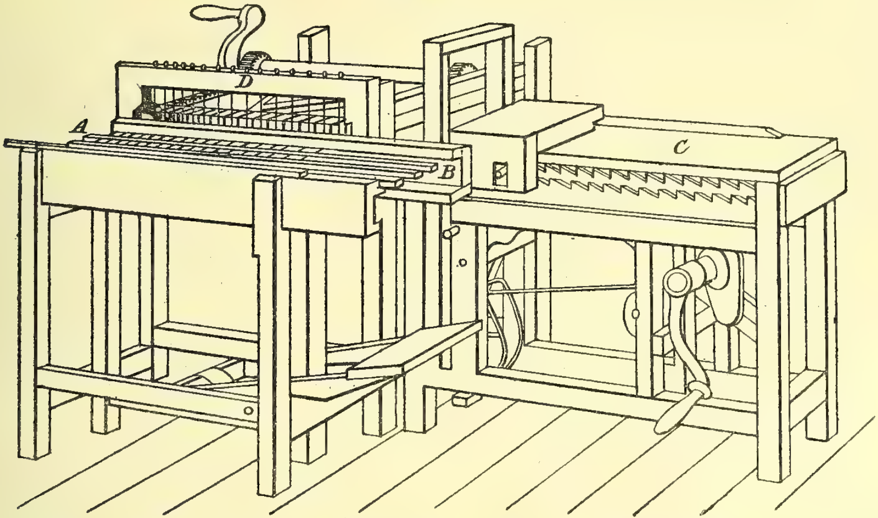

1262.


1264.

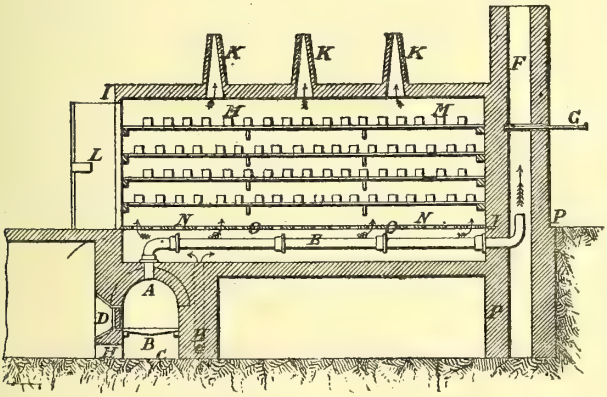
1263.

In connection with the cutting up of soap, it may be conveniently mentioned here that certain soaps undergo a kind of case-hardening process as soon as they have been barred-up. Most of the French mottled soaps are soaked, or even stored, in weak leys, or weak brine, or a mixture of both; and some of the English blue-mottled soaps are also soaked in brine. The usual process, however, is a drying one, which may be carried out either by directing a current of warm, dry air, by a fan or otherwise, against a pile of bars, or by spreading the bars in a drying-chamber, Fig. 1266, which is heated by fire to a temperature short of that at which the soap begins to melt. The fire is kindled in A, and the heated products of combustion pass along E to F, while the air, which enters at H, heated by them rises through the vent-holes O, and, after taking up much moisture from the soap M, passes out through K.

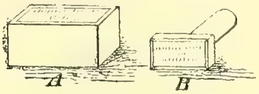
1265.



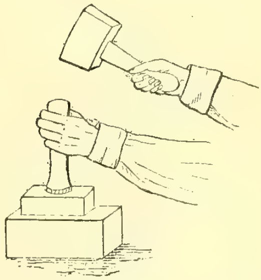
1266.



1267.



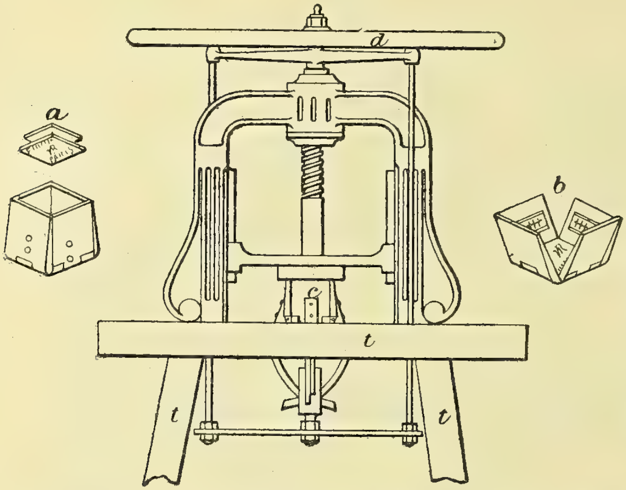
1268.



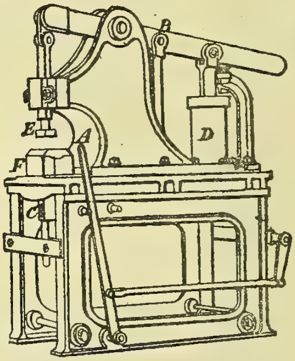
The bars of soap, when freshly cut and still soft, are usually impressed with some words indicating the name or quality of the soap, and the trade-mark or name of the manufacturer. This is most simply done by a hand-stamp, in which the letters or device are cut in hard wood or cast in brass (B); the arrangement and mode of using it with very hard soaps are shown in Figs. 1267–8.

In England, it has long been customary to sell soap in bars 15 in. long, weighing 2½–3 lb.; but during the last 5–6 years a great demand has sprung up among the retailers for ordinary household soaps cut and stamped into 1-lb., ½-lb., and ¼-lb. blocks, a form which also obtains to a very large extent in America. Various parts of each country differ considerably in the shapes preferred for these blocks, and the formation of each kind demands a special set of cutting-wires and of moulds and dies for their production. The 1-lb. and ½-lb. blocks are often "semi-cut," so that they can be readily divided into two ½-lb. and ¼-lb. pieces respectively. The simplest moulds are usually cast in brass, each tablet requiring two, producing an upper and an under surface; but occasionally a mould-box *a b* with hinged sides is employed, with a screw-press, such as is represented in Fig. 1269. With the ordinary tablets, it is necessary to slightly dry them superficially, and to give them a *very* thin coating of oil, that they may not stick to the die. The simplest form of hand-press will stamp upwards of 600 ¼-lb. pieces an hour. For larger tablets, a foot-power press is desirable, such as that made by W. H. King, Philadelphia. All large manufacturers, however, employ some form of steam-power press; one made by Neill & Sons, St. Helens, Lancashire, England, is shown in Fig. 1270. By moving the handle A, steam is admitted into the bottom of the steam-cylinder D; the piston being forced up the cylinder lowers the die E into the die-box F. The rod attached to the lever at B works in connection with a die that is always in the die-box and attached to the spindle C, having a slot for the lever to work in such a manner that when the piston is at the bottom of the steam-cylinder the bottom die is at the top of the die-box, and when the piston is at the top of the cylinder the bottom die is at the bottom of the die-box; thus the stamped tablet, being raised out of the die-box at each stroke, can readily be removed. The great advantage of the lever working the steam valve is, that the attendant must take his hand from the dies before the blow is given, thus preventing accidents arising through the blow being given when the hands are at the dies. Another form (Fig. 1271) is made by Hersey Bros., Boston, and with it a smart workman can mould 2000 cakes an hour; it is supplied with steam at 20 lb. pressure through a tin pipe.

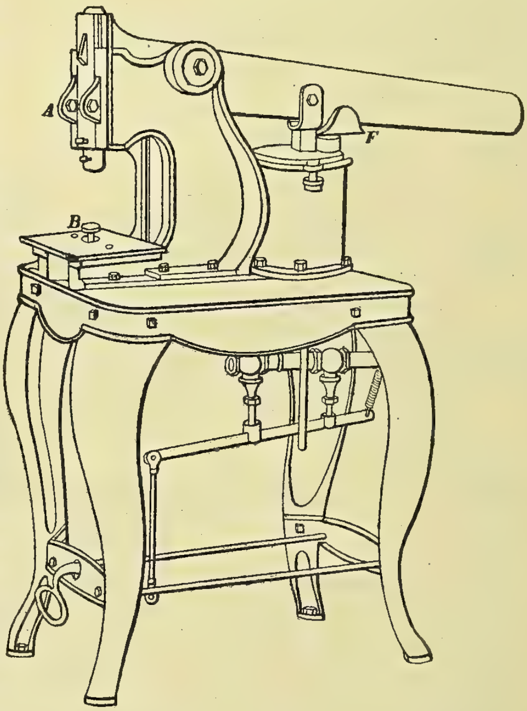
1269.



1270.

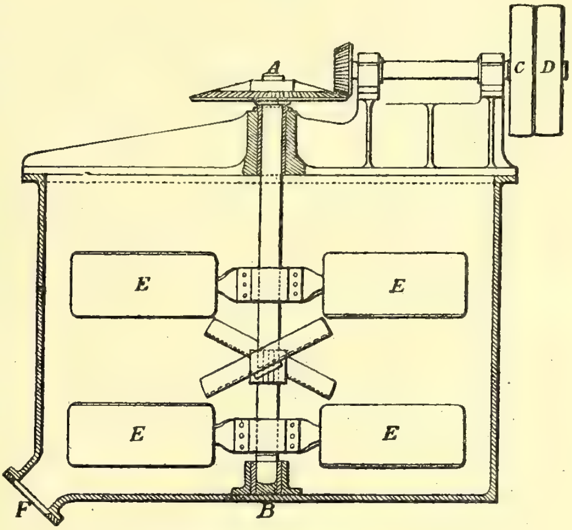


1271.

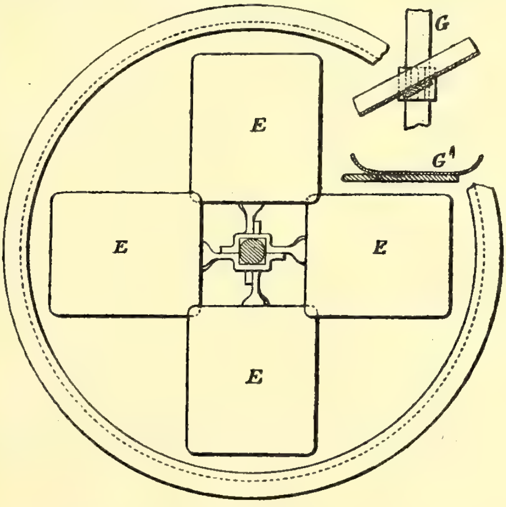


Hitherto, in treating of the fabrication of soap, genuine, unsophisticated, or "neat" soaps, containing not more than 32 per cent. of water when freshly made, have been described. It now remains to deal with the various substances which are mixed with soaps after they have been removed from the copper, by almost every manufacturer, and the mode of their incorporation, known in the trade by the suggestive name of "filling." These may be classed under two heads. The first class, which will be considered somewhat in detail, comprises all those soluble alkaline salts, such as silicates and carbonates, added to soap to increase its detergent power; between the two classes may be placed water, which is always present to a greater or less extent in "filled" soaps, and simply reduces their actual value and economical use; while the second class includes *all insoluble substances*, such as clay, steatite (i. e. soapstone, or magnesian silicate), powdered talc, sulphate of baryta, starch, fecula, and all soluble substances, such as glue and gelatine, which have *no detergent power* in themselves, and are simply added to increase the quantity of water in soaps, or as mere adulterants or make-weights. (A notable example of this is the use of clay or steatite, 5 or even 10 per cent. of which may be mixed with soap without its presence being apparent to the eye.) For obvious reasons, only the use of the first class will be described in the present article; but further remarks on the subject, and methods for detecting and determining the quantity of these adulterants, will be given under the head of Analysis of Soap, pp. 1794–6.

1272.



With the exception of the silicated mottled (blue, grey, and red) soaps, a special description of which will be given, all "filled" soaps are made by incorporating the soap-paste fresh from the copper with the "filling," at a temperature of about 77° (170° F.). On a small scale, this may be readily done by stirring the two together in the soap-frame with a "crutch," which is a perforated piece of wood or iron, whose flat side is attached at right angles to a pole, by which it is moved by a man vertically up and down in the frame. When many tons have to be mixed, however, machinery in some form must be employed, and the choice of the form thereof depends upon the probable consistency of the mixture. Whatever form be decided upon, it is quite essential that it should not merely mix the soap in one plane, but that the contents of various planes should be intermingled; simple rotation of arms at right angles to a vertical shaft is therefore insufficient.



1273.

Such an arrangement is shown in Figs. 1272–3. The blades E of the mixers are set at an angle of 45° on the shaft A B, at the top of which is a pair of bevel-wheels, with fast and loose pulleys C D; F is the discharge-hole, provided with a valve for drawing off the stiff soap. At G G′, are portions of the mixers and scrapers in section. It is desirable, but not necessary, that there should be some means of controlling the temperature of the tanks or vessels in which the "crutching" (as this mixing process is technically called) is carried on. Close steam-worms or steam-jackets are very suitable for this purpose; they should in all cases, however, be cased with a non-conductor, to prevent loss of heat by radiation.

Where very stiff soap has to be crutched, probably the best arrangement is an archimedean screw, which is very largely used in America, where most of the soap made is very stiff; this lifts up the various layers most effectually, and is most conveniently set inside a jacketted cylinder, whose height is about 1½ times its diameter. For crutching soaps that are somewhat thinner, such as are usually made in England, the crutching-machinery designed by Neill & Sons, St. Helens, Lancashire, is very suitable.

One of the earliest methods of cheapening, hardening, and increasing the detersive powers of soaps was that proposed by Dr. Normandy, who mixed "neat" soap with crystallized sulphate of soda, previously melted in its own water of crystallization. The salt re-crystallized in the soap as it cooled, and the soap was thereby considerably hardened, so that it wore better in the wash-tub when rubbed upon clothes, and in this way its detersive power was mechanically increased, although sulphate of soda as such, being a neutral salt, had no detersive power of its own, and its addition to soap really diminished chemically the percentage of soda available for washing. These soaps usually effloresced with a white powder, and gradually fell out of use, especially as raw fatty matters became cheaper.

It was then discovered that the addition of carbonate of soda, or "sal soda," has a remarkable effect in stiffening and hardening soaps to which it is added in a state of strong solution; it also increases chemically its detergent power. This process is very largely employed in America; the amount of soda used depends upon the raw materials from which the soap was made, and upon the quality of the desired product; a very usual proportion is 1 cwt. carbonate of soda crystals (melted) to every ton of soap. Not unfrequently, a solution of pearl-ash (impure carbonate of potash) and common salt, mixed in varying proportions, at a sp. gr. of about 30–35° B., is used for a similar purpose.

Silicated Soaps.—The discovery of methods of manufacturing on a large scale soluble silicates of soda and potash, gave a very important impetus to the soap-trade, since these substances are peculiarly suitable for the purposes now being described. The first application on a large scale was the production of soaps by Christr. Thomas & Bros., of Broad Plain Soap and Candle Works, Bristol, containing both silicate and sulphate of soda, and by these means they were able to produce in 1856 a soap of very great detersive power, which could be sold retail at less than the duty on soap, which had been removed a few years previously. It is usually supposed, however, that the value of silicated soaps was first publicly and officially recognized at the International Exhibition of 1862, when a prize medal was awarded to W. Gossage and Sons, Widnes Soapery, for their samples.

It will be convenient, therefore, to describe here shortly the process of manufacture and properties of the silicates of soda and potash. These compounds, known also as soluble glass or water-glass, may be prepared either by the dry or wet methods. The first is usually adopted by Gossage, Crosfield, and others; it depends on the fact that, at high temperatures, silica plays the part of a very strong acid, capable of displacing acids much stronger than it at ordinary temperatures. On the clean hearth of a reverberatory furnace, 9 parts of soda-ash at 50 per cent. soda are fused with 11 parts clean white sand, or (for the potash salt) equal parts of carbonate of potash and sand. The product may be sold in the dry state, or may be dissolved in boiling water; not unfrequently boiling under pressure is necessary to effect complete solution. If the solution be too alkaline, it may be boiled with rosin, or a fatty acid, or it may be treated with a mineral acid, either liquid or gaseous. Instead of carbonate of potash, a mixture of "salt-cake" (sulphate of soda) and coal may be fused with sand, and the mixture decolorized by arseniate of soda (i.e. a mixture of white arsenic, nitrate of soda, and soda-ash), but a much higher temperature is required in this case, and the wear and tear of the furnace is very great.

For purposes where uniformity of composition is important, it is far better to employ the wet method, as is used by Ransome for artificial stone, and by Christr. Thomas & Bros., Bristol. In this case, white sand or calcined flint is put into a Papin's digester, with a solution of caustic soda at about 12° B. Steam is turned into the jacket, and maintained there at about 25–30 lb. a sq. in.; occasional samples are drawn off by a try-cock, and when all trace of causticity has disappeared, steam is turned off, and the contents are "blown out" into tanks where a few hours' subsidence deprives the solution of all suspended impurity. It is then about 24° B., and may be concentrated, if desired, as far as sp. gr. 1·700. Any mechanical arrangement that moves the flints about, facilitates their solution. Made in this way, the silica and the soda bear to each other a very simple, but a very constant, ratio, viz. 2 to 1, and hence great uniformity of composition is obtained, which is not always the case when soluble silicates are made in the furnace. The compound is usually sold in solution at 140° Tw. (sp. gr. 1·700), and should scarcely vary from this composition:—

Silica	33·00 per cent. to	32·00
Soda	16·50 „	16·00
Other soda salts	2·50 „	3·00
Water	48·00 „	49·00
	100·00	100·00

Solutions of silicate of soda, containing a larger proportion of silica than 2 to 1, cannot be concentrated so far, but are very suitable for many soaps; those containing less silica than 2 to 1 are unsuitable for all soaps, and should be carefully avoided.

Silicate of soda may be mixed with almost any kind of soap, but the strength of the solution employed must be varied according to circumstances. Very weak solutions are often added to "neat yellow soaps," and when employed in this way, it is a good general rule, *ceteris paribus*, to increase the sp. gr. of the solution with the percentage of it employed. Thus, if it be desired to increase the quantity of water in a "neat" soap by 4–5 per cent., a solution at 5° B. will be suitable; while if the quantity of water is to be increased to a total of 50 per cent., a stronger solution (10–12°) is required. This kind, technically known as "run soap," was at one time largely made in America, and still is in England under the name of "London pale." Such soaps are of the consistency of thin treacle when mixed, at say 160–170° F., and are apt to disappear rapidly in hot water, as well as to lose weight when kept.

A more legitimate application of silicate of soda is to mix varying quantities of the concentrated solution with "neat" yellow or curd soaps. This treatment makes yellow soaps much stiffer, and in many cases, by hardening them, adds to their durability. About 5 per cent. of the solution at 1·700 sp. gr. is a suitable quantity, and has much the same effect as the addition of 5 per cent. of carb. soda crystals before described. Much larger quantities than 5 per cent. may be used, but soap so treated is apt to disintegrate unpleasantly in the hands of the consumer. Curd soaps are sold in England with which 15 or even 20 per cent. of silicate of soda at 1·700 sp. gr. have been mixed. These large quantities considerably increase the "soda available for washing," as given by the alkalimetric test (see Soap Analysis, p. 1794).

Aluminate of soda.—As a detergent for mixing with soap, this substance is perhaps even more powerful than silicate of soda. It is chiefly obtained from cryolite, a mineral found in great abundance in Greenland, and may be readily prepared from it by boiling it with lime; cryolite, being a double fluoride of aluminium and sodium, gives up the whole of its fluorine to the lime, leaving a mixture, or compound, of alumina and soda. Like silicate of soda, it is not a definite chemical compound,—as will be seen by the following analyses of different samples:—

	A.	B.
Soda	43·0	44·0
Alumina	40·0	24·0
Water	9·0	32·0
	100·0	100·0

The commercial product is an amorphous white substance, readily soluble in water, in which state it may be mixed with soap, like silicate of soda.

Blue, Grey, and Red Mottled Soaps.—These come under the head of silicated soaps, and are thus made. Two coppers are required, an ordinary steam copper for the first stage, and a fire-copper for the later stages. In the steam-copper, the raw materials are killed, made, and fitted rather open. The fat-mixtures employed are usually vegetable oils, and almost always (though not necessarily) contain a fair proportion of coco-nut- or palm-kernel-oil. When first introduced from Germany, these soaps were made from well-bleached palm-oil and coco-nut-oil, in such proportions as 3 palm- to 2 coco-nut-, or 2 to 1, or even 3 to 1. Latterly, however, palm-kernel- has supplanted coco-nut-oil, and some of the palm- has been replaced by refined cotton-seed-oil. The choice of materials is very much guided by their cost. The fitted soap is shifted off its nigre into the fire-copper, and, to every 1000 lb. of it, is added about 250 lb. solution of silicate of soda at about 20° B.; the exact sp. gr. depends chiefly upon the proportion of palm-kernel- to other oils. The whole is then boiled together with steam and fire, to thoroughly incorporate the mass; when this is complete, the steam is stopped off, and the appearance of the copper is examined. Practice and experience, assisted by chemical analysis, can alone decide when the soap is in "mottling condition"; in that state, it should have about 45 per cent. (or less) fatty acids, and 0·5–1·0 per cent. of sodium chloride, according to the raw materials employed. A good physical test is to take a layer out rapidly upon a cold trowel, and observe its appearance, and the time required for it to "set." A shiny appearance on its surface indicates a deficiency, a frosty appearance, an excess, of mineral salts; if it sets too quickly, and is shiny, more sodium chloride must be added; if it appear frosty, and is long in setting, enough mineral salts are present. So delicate is the process, that the addition of 1 lb. salt to a ton of soap at this stage will entirely alter the appearance of the mottling when cold. When it is in mottling condition, the mineral substance used as mottling is mixed with a small quantity of water, and sprinkled into the copper; it is there thoroughly incorporated with the soap by a few minutes' boiling, and the soap is then transferred as rapidly as possible to *wooden* frames, which are carefully covered up when full, and kept as warm as possible, to allow time for the "mottle to strike." For blue mottle, 5–10 lb. artificial ultramarine per ton of soap are used; for grey, 1–3 lb. finely levigated oxide of manganese. If the soap be cooled rapidly, it will be of a homogeneous blue or grey colour; slow undisturbed cooling is essential to these soaps, and once in the frame, they should never be touched until they are quite cold; it was for them that Gossage devised the pneumatic method of emptying coppers (p. 1781), but a centrifugal pump answers as well. It requires greater skill to make good "blue-mottled" soap than for any other kind, and the manufacture is in the hands of a few large firms. It may be observed here that in these soaps, the mottling, so difficult to produce, is a matter of appearance merely, and that soap with a plain white ground would wash just as well.

Another mode of producing these soaps is to make a portion of the fat employed (usually all the coco-nut-oil, with or without some portion of the other oils) into hydrated soap (p. 1777); the remainder of the fatty matter is made either into a "fitted soap" or a "flat curd" soap, and then transferred to the hydrate previously prepared in another copper; after both are incorporated by thorough boiling, the soap is finished as before directed. This method, for which Blake & Maxwell and C. N. Kottula had various patents, was introduced into England from Germany by the last named about 25 years ago; it is said to produce a more solid and close soap from the same materials than any other method, but when a blue-mottled has to be made, the greatest care must be used to allow no impurities in the materials used for the hydrated soap, or the brilliancy of the blue mottling will be interfered with.

Manufacturers' Soaps.—The various kinds of household soaps having now been described, a few remarks will be made upon the soda-soaps suitable for various manufacturing purposes. Most of these are dissolved in water for use, and hence it is immaterial into what sized bar they are cut. Care, however, should be taken that they *are* dissolved; a case occurred in the writer's knowledge when the quality of a soap was much complained of, as producing greenish stains upon black cloth. The soap-maker asserted his ignorance of anything deleterious in the soap, and subsequent investigations showed that the cloth-manufacturer's workman, instead of completely dissolving the soap, had impregnated the cloth with a solution containing *undissolved pieces*, and the soda in these, not unnaturally, affected locally the indigo and logwood with which the cloth had been dyed.

For ordinary scouring purposes, there are few better soaps than the old-fashioned curd-mottled: many others, however, are used, such as curd soaps made from cheap and inferior greases, and boiled very dry; and fitted soaps from greases and black rosin. For scouring goods of finer quality, a white curd soap from tallow, or tallow and lard, is used, or a curd soap from olive- or cotton-seed-oils, or a mixture of both. The soaps made on Morfit's plan (p. 1771) are also good scouring soaps. As a rule, traces of unsaponified fat (or indeed any extraneous material) are very deleterious in manufacturers' soaps, which, under ordinary circumstances, should contain a very slight excess (as curd and mottled soaps always do) of caustic soda. When for any purpose, as e. g. where delicate dyes are employed, an absolutely neutral soap is required, either a "finely-fitted" soap should be used, or a curd soap from which the caustic leys have been pumped off, and the soap finished by boiling on brine.

According to Crace-Calvert, soaps for dyers' use are not indiscriminately applicable to all colours. To produce the maximum effect in brightening the shade, the soap should be:—

	For Madder Purples.	For Madder Pinks.
Fatty acids	64·4	59·23
Soda	5·6	6·77
Water	34·0	34·00

For some purposes, a soap that will remain liquid in solution at a low temperature is required; such soaps are well made by Morfit's process, and should contain large quantities of oleic acid. For "fulling," this soap is often employed, mixed with curd soap made from unbleached palm-oil only.

Much has been written about the frauds practised by unprincipled soap-makers upon manufacturers using soap, and the latter have been advised, in self-defence, to make their own soaps. Reasons have been given (p. 1777) against this course; it is much to be desired, however, that soap-*users* would take soap-*makers* personally more into their confidence in explaining their requirements, and would themselves superintend (and not leave to their foremen) any experiments made on the working of different kinds of soap. A system, too, on which manufacturers' soaps should be sold, guaranteed to contain a given percentage of fatty matter of a definite quality, with its full equivalent of soda, is greatly needed. Such arrangements, if carried out, would very probably put this trade upon a far better footing than it is at present.

Special Household and Laundry Soaps.—A few of these, including the commoner kind of scented soaps, will now be considered., Cheap toilet soaps are thus made on a large scale. For "honey" soap, a good "neat" yellow soap is taken, and a solution of some yellow dye is mixed with it; 5 per cent. carb. soda crystals, or 5 per cent. sil. soda at 1·700 sp. gr., is then added to stiffen it; the whole is crutched, and scented by the addition at as low a temperature as possible of as much citronella-oil as is deemed necessary. For "brown almond soap," an inferior grade of yellow soap is similarly treated, and scented with about 10 lb. to the ton of mirbane (i. e. nitro-benzol) or artificial almond-oil. When cold, these soaps are cut into bars or cakes, superficially dried, and stamped with one of the foot-power or steam stamping-machines (p. 1784).

Cold-water Soaps.—This term, which has made its appearance within the last 5–6 years, was at first confined to soaps made from very soft materials, but containing a very small amount of water; such, for instance, as those produced by Morfit's process. They are sold at a low rate, and, from their great dryness, may be kept indefinitely without losing weight, a property possessed by scarcely any other household soap; being perfectly pure soap, they are truly economical, provided they are not used with hot water. Christr. Thomas & Bros., of Bristol, and Sinclair, of London, have a great reputation for these soaps, which have been recently introduced. Latterly, however, the use of the term has been appropriated by makers of heavily-watered soaps, which run away in hot water.

Disinfecting Soaps.—In few ways can disinfectants be so agreeably applied to the skin as when incorporated with soap. One of the last introduced, though probably one of the most efficacious, is thymol soap—made solely by Ferris & Co., Bristol. Thymol is a non-poisonous (herein differing from carbolic acid) crystal, about 8 times as powerful an antiseptic and disinfectant as carbolic acid, and is probably the only substance that combines disinfecting properties with a really pleasant smell, that of thyme. The mode of incorporating thymol and phenol (i. e. carbolic acid) with soap is a trade secret; Morfit states that carbolic soaps are best made by his process (p. 1771), using as a basis hot-pressed fat-acid cake, on account of the tendency of carbolic acid to soften the soap-paste.

Carbolic soaps are made in great variety and in large quantities by F. C. Calvert & Co., of Manchester, whose products contain definite specified quantities of carbolic acid of various qualities. Their "medical" soap contains 20 per cent. pure crystal; their toilet and household soaps, 10 per cent.; their domestic soap, 8 per cent.; and their "No. 5" or "scouring" soap, 4 per cent. liquid carbolic and cresylic acids. The comparative antiseptic power of soaps may be tested by adding equal weights, in solution, to equal weights of flour-paste, and, after exposing these to the air under identical conditions, noting the day on which mould first appears on each. The so-called "coal-tar" soap or "sapo carbonis detergens," owes its disinfecting properties to a small quantity of carbolic acid in the coal-tar.

Sand Soap.—Under this heading, occur a number of soaps in which it is sought to unite the chemical power of soap with the mechanical aid afforded by sand in scouring. As much as 20 per cent. of clean sand or powdered quartz is sometimes mixed with soap-paste. In a similar way, soap is made the vehicle of many substances to be applied to the skin, medicinally or otherwise, or in any cleansing process. All these should be incorporated with "neat" soaps, freshly made or remelted, at as low a temperature as possible. Some form of soap is not unfrequently the basis of polishing pastes.

Fine Toilet Soaps.—Three distinct processes are in vogue for the fabrication of these, according to the quality of the product desired. For the commoner kinds, the basis is a good grade of fitted yellow soap, taken direct from the copper, or remelted in a small steam-jacketted pan, or in a Whitaker re-melter, provided with continuous coils of steam-pipe. To this, are added (1) suitable colouring matter, in a soluble form if possible, such as some aniline dye, (2) some mineral salts, as carbonate of soda or potash, salts of tartar, &c., to stiffen and "close" the soap, usually about 5 per cent. in strong solution, (3) at as low a temperature as possible, the perfume. When cold, the soap is cut up into slabs, bars, and cakes, dried, and stamped, as previously described. A few formulæ for perfumes are here given, calculated in each case for 100 lb. soap:—

Brown Windsor.—4 oz. oil of cinnamon,
1 „ „ cloves,
1 „ „ caraway,
2 „ „ sassafras,
2 „ „ bergamot.
Or — 4 oz. oil of bergamot,
2 „ „ caraway,
2 „ „ cassia,
8 „ „ lavender,
1 „ „ cloves,
1 „ „ petit-grain.

Almond Soap.—12 oz. oil of bitter almonds,
4 „ „ lemon.
Honey Soap.— 8 oz. oil of citronella,
2 „ „ lemon-grass.
Glycerine Soap.— 2 oz. oil of cassia,
1 „ „ caraway,
4 „ „ lavender,
1 „ „ mirbane.

In connection with "Brown Windsor" soap, it may be mentioned that the more it is melted, cooled, manipulated, and remelted, the better it becomes, and that the scraps of various sorts of soap that accumulate in the factory are usually worked into this soap.

The intermediate quality of toilet soaps are made by the cold process (pp. 1771–2), from the purest materials that can be prepared, and when the fatty matter (tallow, lard, &c., with occasional coco-nut-oil) and leys have been well stirred together, the colouring matter, perfume, &c., are added, and the whole is left quiet to effect the saponification. As previously directed, the fat should not exceed 49° (120° F.), and ½ its weight of caustic soda leys at 36° B., should be stirred into it; in about 5 hours, when saponification occurs, the temperature will rise to 82·2° (180° F.). This method enables more delicate perfumes to be used, since they are added at so low a temperature. A marbled appearance may readily be given to this soap by drawing, in wavy lines through the mixed fatty matter and leys, a steel blade dipped in colour ground up with oil; to produce a good effect, the peculiar wrist-turn should be used with the blade, such as is required to wield a fencing foil well. It is obvious that these soaps retain their own glycerine.

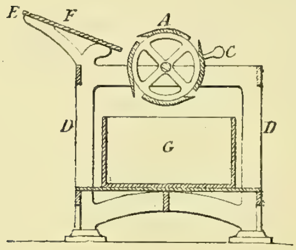
To the perfume formulæ given above, may now be added:—

Rose Soap.—4 oz. oil of rose geranium,
2 „ „ bergamot,
1 „ „ rose,
1 „ „ cinnamon.

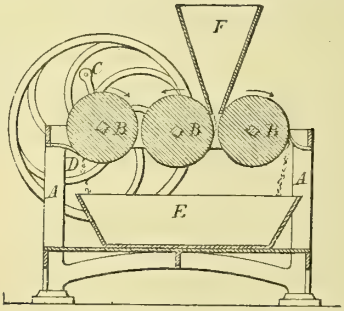
Marsh-mallow Soap.—6 oz. oil of lavender,
4 „ „ lemon-grass.
½ „ „ peppermint,
½ „ „ petit-grain.

The finest qualities of toilet soaps, however, require a great deal of manipulation by costly machinery, which has been chiefly devised by the French, although the Americans, with their well-known mechanical ingenuity, have recently constructed equally good machines. The basis of these soaps, or "stock" as it is technically termed, is usually made by the cold process, from the purest possible tallow, lard, &c., with little if any coco-nut-oil, which, if used, should be the Cochin variety. All the colouring matter, perfume, and other ingredients, are incorporated with the soap under hydraulic pressure, at the ordinary atmospheric temperature; hence the most delicate essences can be employed, even those that are extracted in the cold from plants. The first operation is to "strip" the stock-soap, i. e. to cut it up into strips or shavings; this may be done with a plane by hand, or by a machine (Fig. 1274), whose essential parts are a revolving wheel A, upon which are set 4 or 6 knives, and a hopper F to contain the bars. After stripping, the soap is frequently dried somewhat, and it is then passed through the mill several times, while the colour, perfume, &c., are here added to it. The mill, which is shown in Figs. 1275–6, consists essentially of three cylindrical contiguous rollers B, by whose action the soaps, colour, perfume, &c., after repeatedly running through, are blended into a thick homogeneous paste. When this has been effected, the soap is ready for the final operation, known as "plotting" (from the French, *pelotage*), in which the paste is subjected to enormous pressure, sometimes 3000–4000 lb. a sq. in., to form it into cakes, or into continuous bars from which cakes may be cut. Such a machine, known as Rutschman's hydraulic soap-plotting machine, made in Philadelphia, is shown in Fig. 1277. It may be charged 5 times in

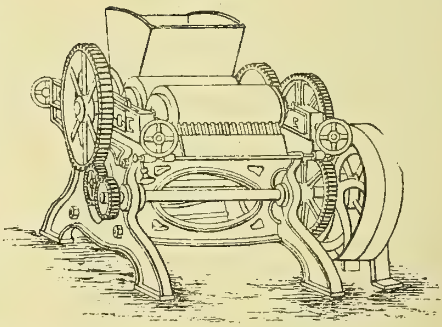
1274.



1275.

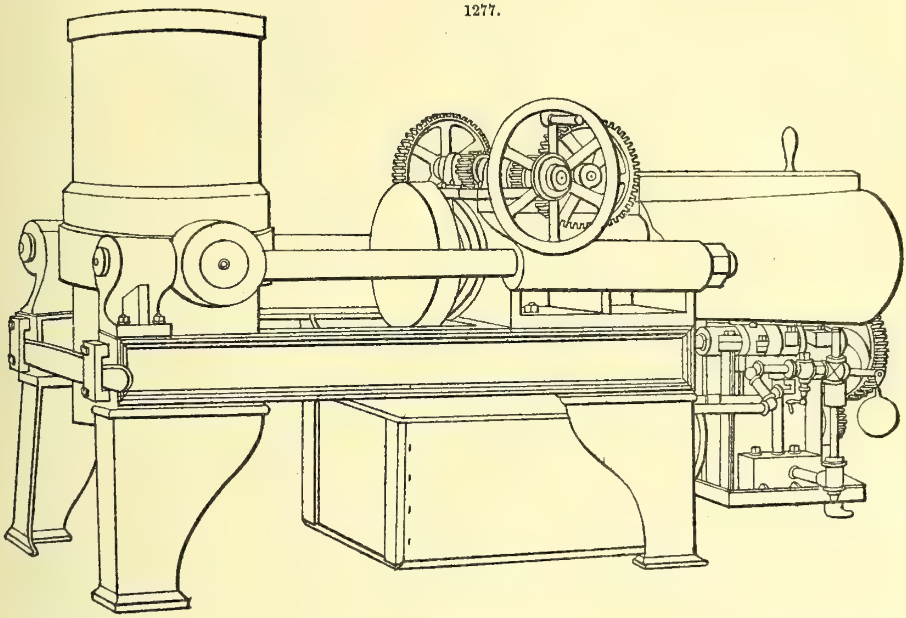


1276.



a working day, and will "plot" 200 lb. at each operation. It is better to let each separate cake be "plotted" by this machine, but if bars are made, and the cakes subsequently stamped, a powerful stamping-press must be employed. Cakes made in this way, are not liable to crack in use, as those made by the other two processes are; before being packed, they are not unfrequently dried, and almost always polished. This may be done by hand with a cloth moistened with alcohol, or, according to Dupuis, by momentary exposure to a current of steam, which, if desired, may be previously passed through a cloth impregnated with any fragrant odour; it is said that no other method gives such a beautiful, even, and lustrous coating.

1277.



A few hints on colour, and formulæ for perfume, are here given. Whenever it is desired to produce a mottled or marbled appearance in the soap, an insoluble colour must be employed; but whenever a uniform tint is required, preference should be given, whenever possible, to colours soluble in either water or alcohol, a condition fulfilled by numerous coal-tar colours. Care should be taken to choose those that are permanent, and unaffected by strong alkali. Salts of chromic acid should be avoided, since they are apt to turn green by transference of some of their oxygen to the fatty matter of the soap; the borate of chromium, known as "Guignet's green," is very stable, and so are ultramarine and vermilion. The finest yellow is produced by infusion of saffron. The resources of the dyer's art are constantly producing new tints, whose properties in relation to soap must be ascertained by that best of all tests, experiment.

The following recipes for high-class toilet soaps may be found useful; the quantities are calculated for 100 lb. soap:—

Orange Soap.

	oz.
Oil of orange peel	8½
„ cinnamon	½
„ thyme	2

Lemon Soap.

Oil of lemon	8½
„ bergamot	4
„ lemon-grass	4½
„ cloves	2

Elder-flower Soap.

	oz.
Oil of bergamot	8½
„ lavender	2
Oil of thyme	2
„ cloves	1
„ cassia	½
„ almonds	½

Millefleur Soap.

Oil of orange (Portugal)	10½
„ lavender	5
„ cloves	2½
„ nutmegs	5
Tincture of musk	5

N.B. Impregnate the fats used in this, with vanilla, ambergris, and rose-leaf.

Violet Soap.

	oz.
Powdered orris root	71½
Oil of lemon	5
,, rhodium	2½
,, thyme	2½
Tincture of musk	5

Finest Honey Soap.

Oil of citronella	8
,, lemon-grass	4
,, cassia	2

Rose Soap.

	oz.
Oil of rose	2½
,, rose-geranium	2¼
,, cinnamon	1
Oil of bergamot	1¼
Tincture of ambergris	½

Glycerine Soap.

I. Oil of lavender	4
,, bergamot	2½
,, thyme	1¼
,, cloves	1
,, carraway	¾
II. Oil of rosemary	6
,, orange	3
,, cassia	1
,, thyme	1
,, mirbane	1

Transparent Soaps.—The peculiar appearance of these soaps is due to the use of alcohol in their fabrication, and it may be applied in two ways. The older method, still employed, is to cut up ordinary soap into shavings, to dry these in heated air, and to dissolve them in half their weight of alcohol of 95°, in a suitable closed vessel provided with a head and condensing-worm, and heated by steam or a water-bath; when the soap is dissolved, and the excess of alcohol evaporated, the soap is drawn off, perfumed, and allowed to cool. Transparent soaps are now, however, usually made by the cold process, but to ensure success, very great exactitude in the proportions of the materials used is necessary, as well as much experience and skill. The fatty matters employed are tallow, coco-nut-oil, lard, castor-oil, and olive-oil, in varying proportions, but all of the purest quality. For 100 parts by weight of fatty matter, 45 parts caustic soda leys at 40° B., and 50–55 parts of alcohol of 95° should be used. One half the leys should be stirred into the melted fat, the temperature of the mixture not exceeding 49° (120° F.), and when thoroughly incorporated the remainder of the leys, mixed with the alcohol, should be added; saponification will take place rapidly, and the perfume should now be added, and the whole cooled very gradually in frames; 20 parts glycerine added to the above will make a good transparent glycerine-soap; occasionally some clear syrup of white sugar is added also. These soaps are seldom coloured, but any colour used in them should be quite transparent; it will be noticed that they do not become quite transparent until they have been exposed to the air for some days.

Solidified Glycerine.—The preparation of this by Price's Candle Co. is a trade secret, but Morfit recommends the following method. Heat to 154½° (310° F.) a mixture of 350 lb. hot-pressed fatty acids, 150 lb. white oleic acid, 200 lb. best rosin. To this, add 135 lb. Jarrow 52° ash (p. 1771) in 25 gal. boiling water. When the soap-paste is quite homogeneous, which should be in about an hour, add 250 lb. pure glycerine, and stir well. If a sample be not transparent when cold, add glycerine until this is the case, controlling the amount of glycerine by testing 2-lb. samples of the soap with glycerine over a gas flame. This soap has the following composition:—Fatty acids, 34·0; rosin, 13·0; soda, 4·6; water, 15·4; glycerine, 33·0.

Since it is beyond the scope of this article to devote more space to the detail of this part of the subject, it may be mentioned briefly that the various shaving-soaps and creams are wholly or in great part potash-soaps; that soap-essences are usually alcoholic solutions of soft-soap; that opodeldoc is a solution of soap in enough alcohol to make a jelly when cold; that "floating" soaps are made by dissolving soaps in a small quantity of water, and agitating the solution violently in contact with air; and that powdered soaps are made from any pure soap, cut into shavings, thoroughly dried, and then ground to fine powder and sifted. It may also be well to call attention to the fact that nearly all the so-called washing-powders, soap-powders, and essences of soap, frequently contain no soap at all, and are merely mixtures of soda-ash, common salt, and sulphate of soda, with occasionally a trace of dry powdered soap.

Theory of the Action of Soap: its Valuation and Analysis.—The mode in which soap facilitates the removal of dirt is by no means clearly understood, and probably depends upon a variety of causes, partly physical, partly chemical. Unquestionably much of its power is due to the alkali it contains, which unites with and renders soluble the grease that forms so large a portion of much of our dirt; but it can hardly be true, as is maintained by some, that the value of a soap depends solely upon its percentage of alkali, since, if that were so, solutions of silicate, carbonate, or aluminate, of soda, containing the same percentage of soda as soap, ought to do as much work, which is notoriously not the case. Further, since the proportion of alkali in a soap is inversely as the equivalent weight of its fatty acids, those soaps with fatty acids of the smallest equivalent weights (e.g. coco-nut-oil) ought to be the most advantageous. Gräger, who advocates this view, gives the following table of anhydrous soaps.

	Equiv. Weight.	Quantity of soap necessary to do the same work as 100 tallow soap.
Oleic acid soap	3800·95	115·1
Palm-oil soap	3558·85	108·7
Tallow soap	3300·95	100·0
Coco-nut-oil soap	3065·45	92·8

Cold water never is in contact with an alkaline stearate or oleate (the soap of commerce therefore) without decomposing it; the neutral salt is resolved into alkali, which dissolves, and an acid salt, which is precipitated as insoluble. Hence soap even in the purest cold water produces turbidity, although, when treated with *warm* water, it dissolves entirely. Again, since every kind of soap, when it leaves the copper, is a more or less concentrated solution of anhydrous soap in water, when cold and firm, it also is subject to the same decomposition; this is the cause of the slender silky crystalline fibres set in a semi-transparent matrix, so often seen especially in "neat" soaps.

When soap is rubbed in use against the surface to be cleansed, it is obvious that its greater or less hardness is an important consideration, since a harder soap requires much labour to detach enough, while a softer soap wastes away rapidly. It has been already shown that, *ceteris paribus*, the hardness of a soap depends upon how much potash it contains; but where soda only is the base, the question of the comparative solubilities of the soda salts of the fatty acids has to be considered. While oleate of soda is freely soluble in 10 parts of water, stearate of soda is scarcely affected thereby; or in other words, the salts of oleic acid are far more soluble than those of stearic. Hence the hardness of a soap depends, not merely upon the base used, but upon the relative quantities of stearic and oleic acids in its composition; this point will be again referred to in the analysis of soaps.

The impurity of the water employed with soap has a material influence upon its consumption. Rain-water, and next to it, river or lake-water, is the best, while spring-water should be avoided if possible; all such water is more or less "hard," owing to the presence in it of salts of lime (chiefly the carbonate and sulphate), some of which may be removed by boiling, or, more completely, by the addition of carbonate of soda. When a soluble soda-soap comes into contact with lime salts in solution, mutual decomposition occurs, resulting in the formation of insoluble lime-soaps, which have no detergent action. Until all the lime has been thus removed, the soda-soap refuses to cleanse, and hence much of it is wasted. It is obvious also that the presence of any acid in the water, or on the surfaces to be cleansed, will decompose soap, uniting with its alkali, and destroying its detergent power. When nothing but hard water can be procured, or when much grease has to be removed, no soap will be found so economical as the old-fashioned curd-mottled, entangled in the interstices of which are appreciable quantities of caustic soda leys.

Considerable light has been thrown upon the manner of removal of dirt by soap, by the researches upon *Pedesis* of Prof. W. Stanley Jevons, F.R.S., who has given this name to a microscopic phenomenon long known as the "Brownian movement" of small particles. When clay is stirred up with water, and the water allowed to stand, it clears itself very slowly, and microscopic examination showed that this was due to a kind of molecular movement of infinitesimally small particles of the clay. To this movement, Prof. Jevons gave the name Pedetic action (*vid.* 'Quarterly Journal of Science' for April, 1878, No. LVIII.), and he found that it was largely influenced by the addition of certain substances to the water containing clay in suspension. Soap and silicate of soda enormously increased the Pedetic action, or movement of the particles (Report of the British Association for the Advancement of Science, 1878, p. 435), and from observations made by Prof. Jevons, and by the writer of this article (who hopes to extend his researches in this direction), it seems clear that in the action of these substances in promoting this molecular movement of extremely minute particles, is to be sought part of the explanation of the cleansing power of soap.

There are few things which are so ill understood in practical life as the *real value*, or, what is the same thing, the proper price of soap. From what has been said, it appears clear that the real value depends upon the amount of dry (anhydrous) soap present, and upon the proportion of stearic, palmitic, and margaric acids to oleic, and to that of the cocinic, laurostearic, &c. In other words, the determination of the following elements is necessary to arrive at an estimate of the value of a soap:—(1) The percentage of water; (2) the percentage of soda available for detergent purposes (*a*), combined with the fatty acids, (*b*) as caustic, carbonate, silicate, or aluminate; (3) the percentage of fatty acids; (4) the melting-point of those fatty acids (see Candles; and Oils, Detection and Analysis, p. 1477).

It would be very greatly to the advantage of all large consumers of soap, as well as to soap-manufacturers themselves, if soaps were to be sold guaranteed to contain so much per cent. of fatty matter of a given melting-point, combined with the full quantity of soda necessary for its complete saponification.

Brief instructions will now be given for the most suitable methods, consistent with accuracy, for the analysis of soap; for fuller information, manuals of technical chemical analysis should be consulted.

Uniformity of Sample.—Great care should be taken to ensure this; since soap loses water rapidly on exposure, the soap should be sliced up in thin pieces, well shaken, and kept in a well-stoppered bottle. Other convenient plans are (1) to weigh out at once all portions required for analysis, (2) to make a standard solution of the soap, say 100 *grm.* in 1 *lit.*, and measure off what is required, taking care to avoid loss by evaporation. In analysing case-hardened soaps (p. 1783), care must be taken to see that the section of the bar includes a proper proportion of skin; sometimes separate analyses have to be made of different parts of a bar of these soaps.

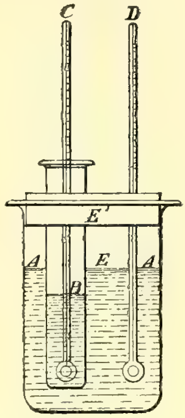
Percentage of water.—About 2 *grm.* of the soap is exposed in a wide-mouthed flask of about 100 *cc.* capacity, to a temperature of 149° (300° F.) in an air- or oil-bath for one hour, and the loss in weight is noted. The flask should be weighed as soon as it is cool, and, where great accuracy is required, should be cooled under a bell-glass in presence of a strong oil of vitriol, as anhydrous soap is very hygroscopic. The operation may be shortened by one-half if a few drops of alcohol be added as soon as the soap has melted; the addition of a known weight of fine dry sand prevents the soap from swelling up too much. No well-made soap should turn brown or discoloured at this temperature.

Percentage of Soda.—A burette (Fig. 1237, p. 1768) is provided, divided into fifths of a cubic centimetre, and a standard solution of acid, such as is directed in works on alkalimetry; either sulphuric or oxalic acids may be used. To determine the *total* percentage of soda present, dissolve 5 *grm.* of the soap in boiling water, and add to it the standard acid solution, stirring and boiling the whole time, until a permanent froth is no longer visible; from the number of *cc.* of acid used, the amount of soda is readily calculated. To determine the soda uncombined with fat, dissolve 10 or 20 *grm.* in water, add enough sodium chloride to precipitate the soap, remove the liquor, re-dissolve the soap in fresh water, repeat the operation, mix both brine solutions together, and estimate the soda therein by standard acid, using litmus to determine when enough has been added. The second result subtracted from the first gives the percentage of soda combined with fatty acids.

Percentage and Examination of Fatty Acids.—A known weight of the soap (10 or 20 *grm.*, if only the percentage is required, 50 or 100 *grm.* if the nature of the fat is to be ascertained) is dissolved in hot water. If any portion refuses to dissolve, as will be the case if steatite, clay, or starch have been mixed with the soap, the solution must be filtered, either in a hot closet, or through a funnel surrounded by hot water; if the filter be previously weighed, the insoluble portion can be weighed upon it after being washed and dried at or above 100° (212° F.); to the clear soap solution, an excess of sulphuric or hydrochloric acid is added, and the whole is gently boiled until the fatty acids are clear and transparent, and all clots have disappeared. If there is reason to believe that the fatty acids will be fluid, or even soft, and greasy, at the ordinary temperature, and a fat percentage only is desired, a weighed quantity of white wax or stearic acid, previously deprived of water [see Oils, p. 1462, (1) *a.*], should be added at this stage. When the cake of fatty acids is cold, the liquid beneath should be removed, and the cake remelted over fresh hot water, to remove all traces of salts and acids. When cold, it may be partially dried with blotting-paper, if it is solid enough not to give up any oleic acid to that absorbent; it should then be all carefully transferred to a tared capsule, heated to at least 127° (260° F.) to expel the last traces of mechanically mixed water, and then weighed, the weight of wax or stearic acid added being of course deducted. Every 100 parts of fatty acids so obtained, represent 105–106 parts of pure neutral fat used to make the soap. In this condition, the fatty acids are hydrates, and from every 100 parts, 3·5 parts must be deducted in stating the analytical results for water chemically combined with them, because anhydrous soap [dried at 149° (300° F.)] does not contain these elements of water.

To ascertain the nature of the fatty acids, the melting-, or solidifying-point of the mixture should first be taken (see Oils, p. 1477). The apparatus suitable is shown in Fig. 1278. The fatty acid is in the inner tube B, surrounded by water, which is gradually heated over a lamp; temperatures are observed by thermometers C D. To detect the presence of, and estimate, coco-nut-oil or palm-kernel-oil, the method recommended in Oils, p. 1746, may be adopted. On the same page, will be found hints for the determination of the quantity of rosin; another method (proposed by Dalican) is here given, with the remark that Sutherland's process, by which the rosin is oxidized by nitric acid, and Rampal's process, in which the rosin is precipitated in a finely-divided state by throwing an alcoholic solution of the fatty acids into water, are both unreliable. Dissolve 10 *grm.* of the soap in 100 *grm.* water, add enough concentrated soda leys to precipitate the soap (p. 1769); some resinates remain in the liquor, which is neutralized, evaporated to dryness, and the resin extracted with alcohol, which may be distilled off, and the rosin weighed (A). Then dissolve the precipitated soap in water, and add excess of barium chloride; collect and dry this baryta soap, and extract it with ether, which dissolves out only the resinates. Evaporate off the ether, and treat the resinates with boiling water and sulphuric acid, which sets the rosin free; it may then, if necessary, be similarly dissolved out by alcohol, or may be merely collected on a weighed filter, and its weight (B) noted; A+B is the weight of rosin in the soap. The portion insoluble in ether may then be suspended in water, decomposed with sulphuric acid, and the fatty acids collected, dried, and weighed.

1278.



For other methods of examining the nature of the fatty acids in soaps, consult Oils—Detection and Analysis, pp. 1462–1477, to which may be added a reference to the amount of information that may be derived from examining, by polarized and ordinary light, under a microscope, the manner of crystallization of thin layers of fatty acid mixtures allowed to cool between two pieces of glass pressed together; some very remarkable results of this method were shown by Price's Candle Co. at the Paris Exhibition of 1878.

Shorter, but less reliable, methods than the above have been frequently proposed for determining the value of soap. To shorten the operation of weighing the fatty acids, many methods have been proposed for measuring them, by collecting them in a long-necked flask, graduated, or in a graduated tube attached thereto. Whenever this is done, the weight can only be arrived at from the estimated sp. gr. of the fatty acids, and as this is very variable, the method is at best an approximate one, though useful in the factory when that sp. gr. is known. Buchner decomposes 16·66 *grm.*, and measures the fatty acids to the ⅕*cc.*, multiplying by 0·93 to get the weight in *grm.* He also gives the following useful table, on the basis that 100 lb. fat produce 155 lb. soap and about 6·25 lb. glycerine; the three last columns are of general use, when the "fatty acids per cent." are determined by weight:—

No. of *cc.* of fatty acids from 16⅔ *grm.* soap.	Sp. gr. of fatty acids.	Mean weight of the fatty acids in *grm.*	Fat used for 100 lb. soap.	"Neat" or grain soap in 155 lb. of soap examined.	100 parts of the soap contain of water, soda, glycerine, &c.	100 parts of the soap contain of real grain soap.
0·5	0·93	0·46	3·13	4·85	97	3
5	„	4·65	31·30	48·50	69	31
6	„	5·58	37·56	58·20	63	37
7	„	6·51	43·82	67·90	57	43
8	„	7·44	50·08	77·60	51	49
9	„	8·37	56·34	87·30	44	56
10	„	9·30	62·60	97·00	38	62
11	„	10·23	68·86	106·7	32	68
12	„	11·16	75·12	116·4	26	74
13	„	12·09	81·38	126·1	20	80
14	„	13·02	84·64	135·8	13	87
15	„	13·95	93·90	145·5	7	93

The Industrial Society of Mulhouse awarded a prize to Cailletet for a method of analysing soap without more weighings than that of the soap itself. Minute instructions are given in the Bulletin of the Society, No. 144, Tome xxix., p. 8. Suffice it to say here that, in the first place, much information may be gained for industrial purposes by attentively observing the behaviour of the soap with hot and cold water; 10 *grm.* of the soap are then decomposed by excess of standard acid in presence of a measured volume of turpentine-oil, the increase in volume of which, multiplied by the sp. gr. of the fatty acids, gives their weight. The acid solution is titrated back with soda, and the soda per cent. is calculated. It is stated that the turpentine does not dissolve the rosin, and that thus the presence of rosin may be detected, and even estimated.

A short way of ascertaining whether there is much besides pure soap, and water, in a sample of soap, is to treat it with strong warm alcohol, which dissolves nothing but the soap, and excess of caustic soda, if any; this last may be removed by a stream of carbonic acid gas. The insoluble residue may be collected on a tared filter, washed with alcohol, dried, and weighed.

The determination of the other constituents of commercial soaps has now to be considered.

Unsaponified fat.—This is very rarely present; 10–20 *grm.* of the soap is cut into fine shavings, and dried at 100° (212° F.); then treated with warm benzol or petroleum-spirit, which is decanted or filtered off into a tared flask; the solvent is then distilled off, or evaporated, when the unsaponified fat, if any, is left behind and weighed.

Glycerine.—A weighed portion of the soap is dissolved in water, and decomposed with slight excess of sulphuric acid; the fatty acids are removed, and the acidulated solution is evaporated to dryness and treated with alcohol; the alcoholic solution of glycerine is separated by filtration into a tared flask, from which the alcohol itself is distilled off.

Carbolic acid.—Mr. C. Lowe recommends the following process. Take 50 grain-measures of aqueous solution of caustic soda sp. gr. 1·345, dilute to 1000 gr.-m.; in this, dissolve by heat 100 gr. of the soap, then add 1000 gr.-m. saturated solution of common salt. Filter off, and wash with brine, the soap thus precipitated; slightly acidify the filtrate and washings with hydrochloric acid, and add thereto enough bromine-water to make the liquid permanently yellow. Warm the liquid till the precipitate melts, then let it cool; remove, carefully dry, and weigh the resulting mass, of which, 331 parts correspond to 94 parts of carbolic acid. If the inferior qualities of carbolic acid have been used, the precipitate, which is bibromocresol, $C_6H_3Br_3O$, forms a sticky mass, owing to the liquid nature of the cresylic acid it contains.

The determination of soluble silica and alumina (as silicate and aluminate of soda), of sulphuric acid (as sulphate of soda), of chlorine (as common salt), and of other mineral constituents of soap, must be made in the acid solution that remains after decomposing the soap with a suitable mineral acid; the estimation of carbonic acid (as carbonate of soda) presents great difficulties. The ordinary methods of inorganic quantitative analysis may be applied in these cases.

Substances Insoluble in Water.—In a properly-made unadulterated soap, these should only consist of colouring matters and mottling. To estimate their amount, dissolve a known weight in water, decant the clear liquid, collect the deposit on a tared filter, wash, dry, and weigh. Organic impurities may be estimated by igniting this residue, and weighing again, when only mineral impurities remain. Starch or farina is detected by iodine; mineral impurities, by the ordinary methods of mineral analysis.

Two or three examples of freshly-made analyses of hard soap are here given; no deduction is made for water combined with the fatty acids (p. 1794).

A good "Primrose" Yellow Soap.

	Per cent.
Water	32·8
Total Soda	6·7
Sodium Chloride	0·2
Fatty Acids	62·3
	102·0

An old-fashioned Grease Mottled Soap.

	Per cent.
Water	29·8
Soda with fat	7·0
Free Soda	0·6
Sodium Chloride	0·1
Fatty Acids	64·7
	102·2

A genuine "Cold-water" Soap.

	Per cent.
Water	22·0
Soda with fat	7·3
Soda with silica, &c.	0·8*
Silica	1·6
Sodium Chloride and Sulphate	0·4
Fatty Acids	70·2
	102·3

* Or 5·0 per cent. sil. soda sp. gr. 1·700.

A Blue (red, or grey) Mottled Soap.

	Per cent.
Water	44·3
Soda with fat	5·2
Soda (free, or) as Silicate	0·8
Silica	1·3*
Sodium Chloride	0·8
Sodium Sulphate	0·3
Mottling and Insoluble	0·7
Fatty Acids	47·5
	100·9

* Equal to 3·9 per cent. silicate of soda at 1·700 sp. gr.

A neutral Curd Soap, for Manufacturers.

	Per cent.
Water	28·0
Soda with fat	7·0
Soda free, &c.	0·0
Sodium Chloride	0·2
Fatty Acids	67·9
	103·1

A few remarks upon the location, prospects, legislative condition, and other general considerations connected with the soap-trade, may fitly close this portion of the article.

This industry is by no means localized in any one part of the British Islands; but, although the total amount of soap made in England is probably greater now than it ever was, the tendency of the last 25 years has been in the direction of concentrating the manufacture in the hands of a few firms. Among these, may be mentioned, W. Gossage & Sons, Widnes, Lancashire; Jos. Crosfield & Sons, Warrington; Hodgson & Simpson, Wakefield; Cook & Sons, Anderson & Cattley, and Cowan & Sons, all of London; Christopher Thomas & Bros., and Lawson, Phillips, & Billings, both of Bristol; Tennant, of Glasgow; Hedley & Sons, Newcastle-on-Tyne; and others. Probably the oldest soap-works in the country are, or at any rate until recently were, to be found in Bristol, which still retains great reputation for its soap. A relic of this may be found at the present day in Holland, in some parts of which no soap can be sold which is not stamped with the word BRISTOL. Of the two soap-works mentioned as now left in that city, the former, belonging to Christopher Thomas & Bros., was established in 1745.

The abolition of the duty on soap in 1853, then about 2*d.* a lb., and producing a revenue of upwards of 1,000,000*l.*, naturally gave an immense impulse to improvements in the manufacture, and various valuable patents were very shortly taken out, the most important of which were those of W. Gossage for silicated soaps, that of T. Thomas for cheap detergent soaps made from mixtures of neat soap, silicate of soda, and sulphate of soda, that of Blake & Maxwell for hydrated soaps (p. 1777), and those of C. N. Kottula, for various improvements in the making of blue-mottled and other soaps. An association of soap-manufacturers in England holds quarterly meetings, at which prices are revised, common action agreed upon, and legislative enactments affecting the trade discussed and watched. All soap-factories, in common with other factories, are subject to inspection by Factory Inspectors acting under the Government, and to the visits of a Certifying Surgeon. In a well-managed soap-works, the sources of nuisance are very slight, and comparatively inoffensive; most of them arise, not from the actual process of soap-making itself, but from the preliminary operations of refining, purifying, and bleaching the fatty matters employed (see Oils, p. 1448, and pp. 1458–1462). They may all be obviated by conducting such operations in closed vessels provided with trunks communicating with the draught of a flue; when impure and rancid fats are used direct for soap-making, the copper should be provided with a cover and a similar trunk. In default of a flue-draught, a fan, or a jet of steam, may be used to create a good current of air.

Since the removal of the duty, there are few means of forming an estimate of the extent of the soap-trade in England; it is known, however, that many of the larger houses make much more than 5000 tons a year, while a few make over 10,000, and it is stated that one house is capable of turning out 500 tons in a week when necessary.

The total annual production in the United Kingdom was estimated at 250,000 tons by Prof. Roscoe, in his inaugural address as President of the Society of Chemical Industry, in June 1881. Our exports of soap in 1880 were as follows:—To the British W. Indies and British Guiana, 69,527 cwt., 71,302*l.*; British S. Africa, 66,563 cwt., 72,928*l.*; Java, 34,013 cwt., 31,510*l.*; China, 30,420 cwt., 28,472*l.*; Spain and Canaries, 24,430 cwt., 24,529*l.*; Portugal, Azores, and Madeira, 23,289 cwt., 24,949*l.*; Gibraltar, 14,897 cwt., 15,455*l.*; Italy, 11,883 cwt., 14,442*l.*; foreign W. Africa, 10,962 cwt., 10,572*l.*; Bombay and Sind, 10,928 cwt., 14,956*l.*; Bengal and Burma, 10,765 cwt., 16,098*l.*; foreign W. Indies, 10,170 cwt., 10,798*l.*; Australia, 7287 cwt., 13,433*l.*; Hong Kong, 7158 cwt., 8334*l.*; Holland, 5674 cwt., 5617*l.*; Channel Islands, 4328 cwt., 6868*l.*; British N. America, 3513 cwt., 4925*l.*; France, 1842 cwt., 4598*l.*; other countries, 44,159 cwt., 60,509*l.*; total, 391,808 cwt., 440,286*l.*

In France, the chief seat of the industry is at Marseilles, while a not inconsiderable amount of common, and nearly all the toilet, soaps are made in Paris. In a report on the exhibits at Paris in 1878, it was stated that the French soap-trade had been for some time stationary at about 220,000 tons per annum, but was then declining, owing to practices not very creditable to the manufacturers.

In Germany, and other parts of the Continent, soft soaps are much more proportionately in vogue for laundry and other purposes, than in England, while the chief hard soaps made are for toilet purposes.

In the United States, Kirk & Co. of Chicago have probably the largest trade, but they are closely approached by Babbitt & Co., and Colgate & Son, of New York. The changes that have lately passed over the trade in America have been already described (p. 1787). It may be said, without fear of contradiction, that while perhaps for fancy toilet soaps the palm must be given to France, England and the United States are pre-eminently the countries where the manufacture of the different varieties of soap is most clearly understood, and carried out on the largest scale, and in the best manner.

Railway- and Waggon-grease.—The first of these consists essentially of a mixture of a more or less perfectly formed soap, water, carbonate of soda, and neutral fat, and is used on the axles of all locomotives, railway-carriages, and trucks that are provided with axle-boxes; while the second is a soap of lime and rosin-oil, with or without water, and is used on all railway-trucks unprovided with axle-boxes, and for ordinary road-vehicles.

The requisites for a good "locomotive-grease" for high velocities are:—(1) a suitable consistency, such that it will neither run away too rapidly, nor be too stiff to cool the axles; (2) lasting power, so that there may be as little increase of temperature as possible in the axles, even at high speeds; (3) a minimum of residue in the axle-boxes.

In practice, it is found that a grease containing 1·1–1·2 per cent. soda (100 per cent.) gives the best results. The process of manufacture is very simple; Morfit's soap-pans, provided with stirrers, p. 1772, Fig. 1240, are the most suitable vessels for the purpose. The fats, usually tallow and palm-oil, are heated to 82° (180° F.), and into them, are run the carbonate of soda and water heated to 93½° (200° F.), and the whole is well stirred together, and run into large tubs to cool slowly. Many railway companies buy a curd-soap made from red palm-oil, dissolve it in water, and add thereto enough tallow and water to bring the composition of the whole to the desired point. It is usual to allow 2½ per cent. for loss by evaporation of water during the manufacture. The composition has to be slightly varied according to the season of the year; the following formulæ for mixing have stood the test of successful experiment; the summer one ran 1200 miles. It should be carefully borne in mind that a chemical analysis of locomotive-grease is no test whatever of its practical value, which can only be determined by actual experiment.

	Summer.	Winter.
	per cent.	per cent.
Tallow	18·3	22·3
Palm-oil	12·2	12·2
Sperm-oil	1·5	1·2
Soda crystals	5·5	5·0
Water	62·5	69·3
	100·0	100·0

The "waggon-grease" is thus prepared. A good milk of lime is made, and run through several overflow-tubs, where all grit is deposited; it is then drained on canvas. If the grease is to be made without water, the paste must be agitated with rosin spirit, which expels the water, and it is then thinned with a further quantity of rosin spirit. The aqueous milk of lime, or the mixture of lime and rosin-spirit, is then stirred together with a suitable quantity of rosin-oil in a tight barrel furnished with a shaft and stirrers, without the application of heat, after which, the whole is run out into barrels to set. Many other ingredients are often stirred in, such as "dead oil," petroleum residues, graphite, sea-weed jelly, silicate of soda, oil refiners' foots, micaceous ores, steatite, Irish moss, &c.

A careful estimate was made in 1865, compiled from various reliable sources, by Watts, of the total quantity of anti-friction greases made in the United Kingdom in a year, of which the following is an abstract:—

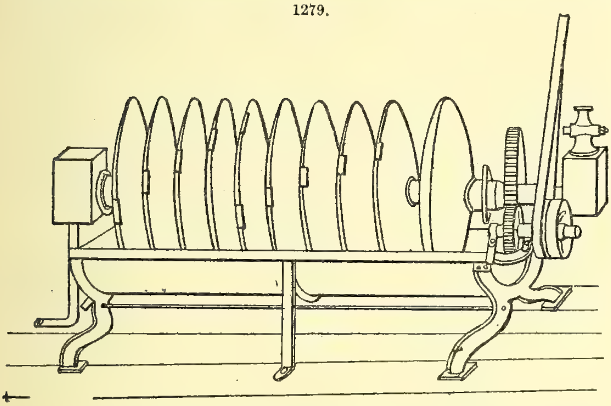
		Tons.
Railways	11·7 cwt. per mile per year	6,358
	1·42 cwt. per 1000 tons coal	6,108
	Other minerals, &c.	711
	Agricultural carts	2,130
	Trade and other carts, &c.	2,070
	Total	17,377

Glycerine (Fr., *Glycérine*; Ger., *Oelsüss, Oelzucker, Glycerin*).— Few things in the history of chemical industry are more wonderful than the enormous development in the use of this substance, which, a few years ago, was thrown away as a waste product, but which now finds so many useful applications in the arts and sciences. The researches of Chevreul, which demonstrated the constitution of fats, showed that glycerine exists in nearly all neutral fats (see p. 1764) in a combined state, and small traces of it have lately been discovered uncombined in palm-oil. It is formed, as Pasteur has shown, in the process of fermentation, 100 parts cane-sugar forming 3·5 parts of glycerine. Recent researches have also made it clear that its compound with phosphoric acid is the starting-point of a number of complex constituents of the brain. For practical purposes, however, glycerine is always obtained from the bye-products of candle-, and quite lately, of soap-factories. Cap worked out the first process for preparing it on a commercial scale from the waste liquor of the saponification of tallow by lime, in the first stage of stearic acid making (see Candles, p. 579). Early in 1854, Tilghman produced it by pumping an emulsion of 2 parts tallow and 1 part water through a coil of pipe heated to 322° (612° F.), after which, the emulsion separated into two layers, the upper one of fatty acids, and the lower of glycerine and water. Several modifications of this were afterwards patented, but the only one worked on a large scale was that of G. F. Wilson and G. Payne, dated July 24, 1854, under which, enormous quantities of glycerine have been made by Price's Candle Co. In this process, neutral fats are put into a still provided with a fine steam-worm, and a fractional condensing apparatus of large surface, similar to that described in Candles, p. 581; they are then heated to between 288° and 315° (550°–600° F.), and plenty of superheated steam is injected; mixed vapours of fatty acids, glycerine, and water are carried over to the condenser, where the divisions nearest the still collect only fatty acids, while those farthest from it yield mixtures of fatty acids with glycerine and water in various stages of concentration. Glycerine so made can be concentrated in a vacuum-pan. Care must be taken that the temperature does not exceed 315° (600° F.), and that plenty of steam is present, else some of the glycerine is decomposed, and acrolein, a compound most irritating to the eyes, is formed—

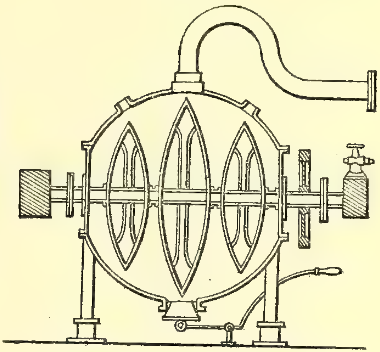
$$\begin{array}{ccccc}\text{Glycerine} & = & \text{Water} & + & \text{Acrolein}\\ C_3H_8O_3 & = & 2H_2O & + & C_3H_4O\end{array}$$

Raw glycerine is also prepared from the water employed to wash the fatty acids after acidification (p. 581) of the neutral fats. The acid liquid is neutralized by carb. lime, or carb. baryta, either of which may be added until effervescence ceases; it is then concentrated to 28° B. in an open, shallow, cast-iron pan. Of late, however, glycerine has become sufficiently valuable to cause candle-manufacturers to adopt that method of preparing fatty acids which gives them the greatest yield of glycerine from neutral fats. This process, called the autoclave, as patented by De Milly on Nov. 19, 1856, is now very extensively used for glycerine making, both on the Continent of Europe and in England, and is thus conducted. About 1 ton of fat, usually mixed tallow and palm-oil, is heated with 2 per cent. lime and $\frac{1}{3}$ the fat-volume of water in an upright Papin's digester to 8 atmos. pressure for 4 hours. The whole is then blown out into a tank, and the "sweet-water" is run off. The lime-soap is decomposed in the usual way with sulphuric acid, and the resulting fatty acids are either pressed, or acidified and distilled for stearic acid. (See Candles, p. 581.) It is then concentrated in a modification of the "Wetzel" evaporating-pan (originally introduced for sugar-boiling), constructed by Chenaillier, Paris. This *évaporateur universel*, as he terms it, which is very economical and effective, is shown in Fig. 1279, and consists essentially of pairs of saucers set edge to edge upon a hollow central revolving shaft, through which, steam passes to the interior of the saucers (the waste steam from a high-pressure engine will do); the lower edges of the saucers dip in a jacketted trough of the liquid to be evaporated, and when they are revolved, layers of this are brought up and speedily concentrated on their surface. It may also be worked in a vacuum as shown in Fig. 1280.

1279.



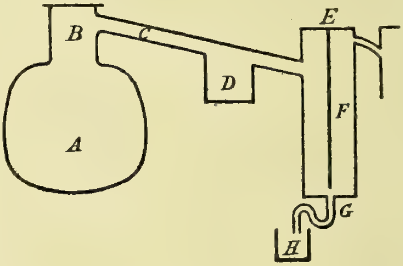
1280.



Evaporation is continued to 26° B., when the glycerine is of a brownish colour, and known as "raw," in which state it is sold for many purposes. At Price's Candle Company's works the further purification is conducted as follows. The raw glycerine, sp. gr. 1·245–1·250, is heated in a jacket pan with that kind of animal charcoal known as ivory-black, and is then distilled; this alternate treatment is repeated as often as may be necessary. The distillation is performed with superheated steam in a copper still provided with copper fractional condensers (the same as shown in Fig. 463, p. 581, but omitting the right half of the apparatus, including the tanks G), the still being also heated externally; the operation is performed at as low a temperature as is consistent with distillation, usually about 227° (440° F.). The number of distillations depends upon the quality of the raw glycerine and the purity of the product demanded. Of the six runs, Nos. 1, 2, and 3 usually give pure glycerine, while the dilute condense-products from Nos. 4, 5, and 6 are generally returned to the still, though occasionally concentrated in an *évaporateur universel*, or in a vacuum-pan. Some stills hold as much as 3 tons, but they are usually smaller, and in all cases the process is conducted very slowly. A form of still and condenser much used on the Continent of

Europe is outlined in Fig. 1281. External heat and injected superheated steam are used to effect distillation. The still A has an unusually large head B, and the goose-neck C is provided with a catch-box D, in case the still-contents should, as sometimes happens, boil over; the fractional condensers E are upright cylinders with longitudinal partitions F running nearly their whole length; the condensed products run out through G into receptacles H. The whole apparatus is of iron, and usually made to distil ½ ton at a time; in some cases, the process is conducted continuously, with a properly arranged feed.

1281.



Enormous quantities of glycerine are run to waste in the spent leys (p. 1779) of the soap-maker. One of the earliest attempts to extract it was a patent by H. Reynolds, June 10, 1858, for concentrating the spent leys, and distilling off the glycerine by superheated steam between 193½° and 204½° (380°–400° F.); the large quantity of sodium salts, especially sodium chloride, were found, however, to be an almost insuperable difficulty. On March 31, 1879, a patent was taken out by C. Thomas, W. J. Fuller, and S. A. King, of Broad Plain Soap Works, Bristol, by which process the first successful production of crude glycerine from spent soap leys was introduced into commerce, and several tons per week are now manufactured. The specification states:—"We evaporate the spent or partially spent leys until the boiling-point of the liquid rapidly rises, when nearly all the salts that can be thrown down by simple evaporation are deposited in the pan. The resulting liquor is chiefly composed of raw or impure glycerine. This we draw off into a second pan, and boil it with excess of fatty acid, which, readily combining with some of the salts in solution, separates them from the liquor, and at the same time removes from it the fine crystals of salt formed during this operation. After this treatment, we skim off the saponified fatty matter, allow the liquid to cool, and filter it to remove the gelatinous, albuminous, and other impurities. The clear liquid may then be refined, distilled, or concentrated, as desired."

The recent extremely rapid rise in the price of glycerine has caused much attention to be directed to this abundant source of it. Victor Clolus, of Billancourt, near Paris, has patented a process for its recovery from soap-boiler's waste, which will (Oct. 1881) shortly be worked in England also; and H. Flemming, of Kalk, has patented in Germany (No. 12,209) a process for removing glycerine from spent leys by dialysis, a membrane of parchment-paper serving as the diaphragm through which the crystalline salts present in the glycerine diffuse themselves. Another process has been proposed, according to which, the salts are said to be removed from spent leys by saturating the latter first with carbonic acid gas, and then with hydrochloric acid gas.

Although evaporation and distillation are the usual methods of purifying glycerine, the action of cold upon more or less dilute glycerine is sometimes employed in conjunction with them, especially by Sarg, at Vienna. When an aqueous solution of glycerine partially freezes, the frozen mass contains more water than the remaining liquid, hence some amount of concentration may be thus effected. The following table gives the freezing-points of such mixtures:—

Glycerine Per Cent.	Sp. Gr.	Freezes.	Glycerine Per Cent.	Sp. Gr.	Freezes.
10	1·024	− 1° C.	60	1·159	Below − 35° C.
20	1·051	− 2°·5	70	1·179	
30	1·075	− 6°	80	1·220	
40	1·105	− 17°·5	90	1·232	
50	1·127	− 31°·3	94	1·241	

Another authority gives:—

Glycerine solution sp. gr.	10° B.	12° B.	14° B.	15° B.
Melting-point ..	− 9° C.	− 13° C.	− 18° C.	− 21° C.

In January 1867, some glycerine sent in tin cans from Germany to England froze into pea-sized octahedral crystals; these, while melting, had a constant temperature of 7°·2 (45° F.), but would not freeze again even when cooled to − 18° (0° F.). According to Werner, commercial glycerine will freeze more readily if chlorine gas be passed into it. In purifying glycerine by cold, the whole mass is cooled to nearly 0° (32° F.), and some crystals of solid glycerine are added; almost the whole mass solidifies on agitation, and a centrifugal machine is used to separate the solid from the liquid parts. Treated in this way, glycerine at 28° B. yields crystals which, when melted, are 30°·8 B.

Pure glycerine is a viscid, colourless, and transparent liquid, with an intensely sweet taste, soluble in water in all proportions, in alcohol, chloroform, and carbon bisulphide, but not in ether; its sp. gr. is 1·267; it solidifies at − 40° (− 32° F.) to an amorphous mass. When distilled, it decomposes, unless steam be present, hence its boiling-point cannot be accurately determined at atmospheric pressure. According to Bolas, at 12·5 *mm.* pressure, it boils at 179°·5 (355° F.), and at 50 *mm.*, at 210° (410° F.), while Heminger gives 179° (354° F.) as its boiling-point under 20 *mm.*

It burns with a clear flame like oil, if there be free access of air, and a high temperature for kindling it.

From one point of view, in its chemical relations it is an alcohol, and although the ferments that excite alcoholic fermentation will not ferment pure glycerine, it may be fermented by a hitherto undescribed *bacterium.* Just as acetic acid and alcohol, interacting, form water and acetic ether, so acetic acid and glycerine, interacting, form water and *mon*acetin. *Tri*acetin is a natural glyceride, occurring in cod-liver-oil. This brings to mind the other aspect of glycerine, viz. as the base of the natural glycerides, in which, it requires three equivalents of a fatty acid, and hence is considered a tri-acid base, or, in the language of modern chemistry, a trivalent alcohol radicle. Its formula on this view is $C_3H_5(OH)_3$, and its relation to its most abundant sources is here shown:—

Tristearin	$C_3H_5\ (OC_{18}H_{35}O)_3$	Tallow.
Triolein	$C_3H_5\ (OC_{18}H_{33}O)_3$	
Tripalmitin	$C_3H_5\ (OC_{16}H_{31}O)_3$	Palm-oil.
Triricinolein	$C_3H_5\ (OC_{18}H_{33}O_2)_3$	Castor-oil.
Tributyrin	$C_3H_5\ (OC_4H_7O)_3$	Butter.
Triacetin	$C_3H_5\ (OC_2H_3O)_3$	Cod-liver-oil.

Next to water, glycerine is the most powerful solvent known. It dissolves bromine, iodine, and carbolic acid better than water does. Klever gives a long table of the solubilities of different substances in 100 parts of glycerine, from which the following is taken:—93 sodium carbonate, 40 alum, 25 green vitriol (ferrous sulphate), 20 lead acetate, 20 sodium chlorate, 0·50 quinine and other alkaloids, 1·9 iodine, 0·20 phosphorus, 0·10 sulphur.

With baryta, strontia, and lime, it forms compounds insoluble in water, not precipitable by carbonic acid. Anhydrous glycerine dissolves caustic potash and soda, oxide of lead, all deliquescent salts, the sulphates and chlorides of potassium and sodium, and of copper, the vegetable acids and alkaloids. It mixes with water in all proportions; the following table will be found very useful commercially:—

TABLE OF QUANTITY BY WEIGHT OF WATER IN 100 PARTS BY WEIGHT OF DILUTE GLYCERINE AT 17½° (63½° F.).—[F. HOFFMANN.]

Sp. Gr.	Per cent. Water.	Sp. Gr.	Per cent. Water.	Sp. Gr.	Per cent. Water.
1·267	0	1·212	17	1·161	34
1·264	1	1·209	18	1·159	35
1·260	2	1·206	19	1·156	36
1·257	3	1·203	20	1·153	37
1·254	4	1·200	21	1·150	38
1·250	5	1·197	22	1·147	39
1·247	6	1·194	23	1·145	40
1·244	7	1·191	24	1·142	41
1·240	8	1·188	25	1·139	42
1·237	9	1·185	26	1·136	43
1·234	10	1·182	27	1·134	44
1·231	11	1·179	28	1·131	45
1·228	12	1·176	29	1·128	46
1·224	13	1·173	30	1·126	47
1·221	14	1·170	31	1·123	48
1·218	15	1·167	32	1·120	49
1·215	16	1·164	33	1·118	50

Commercial glycerine is liable to contain various impurities, arising from its mode of preparation; also certain adulterants, of which cane-sugar and glucose are the chief. Glucose may be detected by the brown colour formed when the suspected glycerine is boiled with caustic soda; cane-sugar is shown by its deposition when the glycerine is agitated with chloroform, or, more certainly, by a polarizing saccharimeter, since glycerine has no rotatory action on the plane of polarization. Lead is detected by sulphuretted hydrogen; lime, by the addition of alcohol and sulphuric acid, a white precipitate of calcium sulphate being formed; butyric and formic acids, by the characteristic smell of their ethers, produced by boiling the suspected glycerine with alcohol and strong sulphuric acid; oxalic acid by the addition of calcium chloride and ammonia; sodium chloride, by the addition of silver nitrate, which should give no precipitate with pure glycerine after 24 hours' standing. A rough and ready test for impurities generally is to agitate the glycerine with an equal bulk of chloroform, when they collect in the intermediate layer.

Traces of glycerine present in other substances, may be detected by the formation of formic ether (which smells of peach-blossom), produced by boiling glycerine with manganese binoxide, alcohol, and sulphuric acid.

The uses of glycerine are very numerous, and are almost daily increasing in number. Its applications in pharmacy are almost endless; it is used wherever a substance requires to be kept more or less moist, e. g. modelling-clay, tobacco, paper for printing, adhesive gum, &c.; also in spinning, "dressing," weaving, rope-making, and tanning. It is used in gas-meters, and in floating compasses, to lower the freezing-point of the water therein used; it is an excellent preservative medium for meat, and for natural history specimens, to which latter purpose it was first applied in 1856 by Dr. Carpenter, F.R.S. Glycerine is also of great importance as the starting-point of other chemical products of great value, one of the most valuable of which is nitro-glycerine, the fabrication of which has been described on pp. 897–902. For this purpose, it must contain no sodium chloride. The engineers of the Panama canal estimate their requirements of nitro-glycerine at a minimum of 8000 tons, equal to about half that quantity of raw glycerine. Besides nitro-glycerine, two other important products are obtainable from glycerine, viz. isopropyl iodide, and allyl iodide, each of which serves as the starting-point of a large series of chemical products, many of them of utility in the arts. They are formed by heating glycerine with hydriodic acid, thus:—

$$C_3H_5(OH)_3 + 5\,HI = 2\,I_2 + 3\,H_2O + C_3H_7I \text{ (isopropyl iodide.)}$$
$$C_3H_5(OH)_3 + 3\,HI = I_2 + 3\,H_2O + C_3H_5I \text{ (allyl iodide.)}$$

When oxalic acid is heated in contact with glycerine, the former breaks up into formic acid and carbon dioxide. This process is much used in the preparation of formic acid, the glycerine employed not being consumed, but merely successively decomposed and recomposed.

The total production of glycerine yearly was estimated by Riche, in a report on the Paris Exhibition of 1878, at 10,000,000 *kilo.*, with a value of 5–6 million *fr.* The production was thus distributed:—France, 4000 tons; Germany and Austria, 1500; Holland, 900; Russia, 900; Belgium, 800; Italy, 400; England, 300; Spain, 100.

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(See Alkali; Candles; Oils and Fatty Substances; Resinous and Gummy Substances.)

SPICES AND CONDIMENTS (Fr., *Épices*, *Assaisonnements*; Ger., *Würze*).

The terms "spice" and "condiment" are applied to those articles which, while possessing in themselves no nutritious principle, are added to food to render it more palatable. Spices are exclusively of vegetable origin, and generally consist of aromatic fruits. Condiments may be regarded as embracing mineral substances like salt, artificial compounds such as ketchup, and bitters used for provoking an appetite. Salt is so much more important in chemical industries than as a flavouring, that it has been described in a separate article (see pp. 1710–40). The present article will include the dozen and a half spices which chiefly figure in commerce, as well as that foundation of nearly all sauces, the Chinese soy.

Aniseed (see pp. 334–5).—The common anise (*Pimpinella Anisum*) is a native of the Greek, Turkish, and Egyptian shores of the Mediterranean, but is nowhere found growing wild. It is cultivated in Touraine and Guienne (France), near Alicante (Spain), in Puglia (S. Italy), in Malta, in Bohemia, Moravia, and several parts of N. and Central Germany, in the Russian districts of Orel, Tula, Woronesh, and Charkov, in Greece, Morocco, Persia, N. India, and some countries of S. America. Of the fruits forming the common "aniseed" of commerce, there were exported from Mogador, in 1880, 2 serons, 8*l.*, to France; from Bushire, in 1879, 500 *rupees*' worth to India; from Revel, in 1878, 569 *poods* (of 36 lb.) to Great Britain; from Guatemala, in 1878, 16½ *quintals* to Belize.

The true "star-anise," a fruit having exactly the same odour as anise, and from which an oil of anise (see p. 1416–7) is also prepared, is the *hwai hiang* of the Chinese, the fruit of *Illicium anisatum*, a small tree (25–30 ft.) indigenous to the countries lying south of China, and long since introduced into and now largely cultivated in the Chinese provinces of Yunnan and Kwangse. On the other hand, the fruit of the Japanese species (*I. religiosum*), called *skimi*, *fanna skimi*, or *somo* in

Japan, and *ao-wu-su* in China, though occasionally shipped from Japan to this country in ignorance, is a potent poison, and may be distinguished by having neither odour nor flavour of anise, but a smell resembling bay-leaves, and scarcely any taste at all. In English commerce, it is sometimes found mixed with the Chinese star-anise. Chinese anise is imported into Japan for use as a spice.

The fruits of other species deserve mention here as possible adulterants of or substitutes for the genuine star-anise. They are:—(1) *I. parviflorum,* of the hilly regions of Georgia and Carolina, fruit having a sassafras-like flavour; (2) *I. floridanum,* the "poison-bay" of Alabama and Florida, the fruit divided into 13 (instead of 8) carpels or rays, and having the flavour of true star-anise; (3) *I. Griffithii,* on the Bhotan and Khasia Hills at 4000–5000 ft., fruit bitter and acrid in flavour, and having an odour between bay-leaves and cubebs; (4) *I. majus,* on the Thoung Gain range in Tenasserim at 5500 ft., fruit sold as *bunga lawang* in Singapore, of mace-like flavour, and used as a febrifuge.

Large quantities of star-anise are exported from China to England and the Continent, as well as overland to Yarkand and India. Macao, in 1879, shipped 8000 *piculs* (of 133⅓ lb.), the produce of Kwangse. Pakhoi exports paying duty were valued at 9045*l.* in 1879, the average weight of the shipments being 6500 *piculs.* Shanghai, in 1879, despatched 631 *piculs* of whole, and 124 of broken. The approximate London market values are 37–40*s.* a cwt. for common anise, and 75–95*s.* for China star.

The essential oils of anise and star-anise are described on pp. 1416–7.

Capsicums, Chillies, Cayenne-, Red, Pod-, or Guinea-Pepper (Fr., *Piment* or *Corail des Jardins, Poivre d'Inde,* or *de Guinée*; Ger., *Spanischer Pfeffer*).—Of the many species or varieties of *Capsicum,* two contribute to the spice found in commerce:—*C. fastigiatum* [*minimum*], occurring wild in S. India, and extensively cultivated in tropical Africa and America; and *C. annuum* [*longum, grossum*], of Algeria. Several varieties of the *C. annuum* have little or no pungency; one of these is abundantly grown in Hungary, forming the *paprika* of the Magyárs. Another variety cultivated in Spain is imported into this country in powder for giving to canaries, to improve the colour of their feathers. The smaller varieties (*C. fastigiatum*) are usually known as "chillies" or "bird pepper." The Nepal capsicums, which have an odour and flavour resembling orris-root, are the most esteemed as a condiment. The fruits of the first species are not more than ½–¾ in. long, while those of the second reach 2–3 in. Capsicum pods and the seeds dried and pounded are considerable objects of trade. In 1871, Sierra Leone exported 7258 lb., and Natal, 9072 lb., while Singapore, in the same year, imported 1071 cwt., chiefly from Penang and Pegu. Bombay imported 5567 cwt., principally from the Madras Presidency, in 1872–3, and exported 3323 cwt.

Caraways (Fr., *Fruits* or *Semences de Carvi*; Ger., *Kümmel*).—The mother-plant of caraway "seeds" (*Carum Carvi*) grows in moist meadows, widely throughout Europe and Asia, from Iceland to the Himálayas, and in a prescribed district of N. Africa, partly wild, partly under cultivation. In England, it is found wild in Lincoln, York, and some other shires, and is cultivated with coriander on clay lands in Kent and Essex. It needs much care and diligence, yielding in the 2nd year a crop which is harvested in July, by cutting with a hook at about 1 ft. from the ground, and is ready for threshing a few days later, the produce of "seeds" being 4–8 cwt. an acre. In Germany, the cultivation is largely carried on in Moravia, as well as in Prussia, especially near Halle, and in the districts of Erfurt and Merseburg, the yield from the two latter being stated at 30,000 cwt. yearly. In Holland, quantities are grown in N. Holland, Gelderland, and N. Brabant, the plants being wild in the two latter provinces. The fruits are exported from Finmark (Norway), and from Finland and Russia, the plant growing throughout Continental Scandinavia, Arctic, Central, and S. Russia, and Siberia. Thence it extends into Persia, the Caucasus, Armenia, and the high alpine region of Lahoul, W. Himálaya. It is also found throughout E. France, the Pyrenees, and Spain. The statement that it is much cultivated in Iceland, is open to great doubt. A large variety is grown in isolated districts in Morocco, viz. about El Araiche and around Morocco City. The exports thence were 952 cwt. in 1872; and from Tangier to Great Britain, they were 46 cwt., 37*l.*, in 1878, and 120 cwt., 118*l.*, in 1880. Memel, in 1879, shipped 2057 cwt., 2777*l.* Our total imports in 1870 were 19,160 cwt., mainly from Holland. The kinds distinguished in the London market are English, Dutch, German, and Mogador.

The essential oil of caraway is described on pp. 1418–9.

Cardamoms (Fr., *Cardamomes*; Ger., *Cardamomen*).—There are two varieties of the cardamom plant affording the commercial spice. *Elettaria* [*Alpinia*] *Cardamomum,* growing both wild and cultivated in the moist, shady, mountain forests of N. Canara, Coorg, and the Wynaad, at 2500–5000 ft. elevation, where the mean temperature is 22° (72° F.), and the annual rainfall 121 in.; and var. β., giving longer and larger fruits, found wild in the forests of Central and S. Ceylon. The latter are known in commerce as Ceylon cardamoms. They are about 1–1½ in. long, ½ in. diam.; of a greyish colour, and are not bleached like the ordinary cardamoms. Large quantities of the fruit are collected from wild plants, but cultivation is also extensively carried on, varying considerably in the different districts.

In Travancore, Coorg, and the Wynaad, the plan adopted is as follows. In the dry season, spots are selected on a slope of W. or N. aspect in the shady forest where some of the plants are already growing, and a patch measuring some 250–350 ft. by 30–40 is cleared of underwood in such a situation that it will be covered by felling one of the huge forest trees, whose destruction will admit sun and light. The cardamom plants spring up quasi-spontaneously, and attain a height of 2–3 ft. during the following monsoon, after which, the patch is weeded, fenced, and left for a year. The plants commence to bear about 3½ years after their first appearance, and continue productive for 6–7 years, the yield being 28–48 lb. per annum from an acre of forest containing 4 patches of 484 sq. yd. in area. In Travancore and Cochin, cardamoms are monopolies of the native rajahs. All the produce of the former State is conveyed to the port of Aleppy [Alapalli], where it is sold by auction chiefly to Moplah merchants for distribution over India, and the finest for export to England.

The plant is raised from seed both on the lower range of the Pulney Hills, near Dindigul, at about 5000 ft., and in the betel-nut plantations of N. Canara and W. Mysore. In the former locality, the *sholas*, or forests which are moist all the year round, are cleared of underwood and small trees; the cardamoms are sown, and, when a few inches high, are planted out in ones or twos under the shade of the big trees, requiring 5 years before bearing fruit. In the betel-gardens, the plants derive shade from the palms and plantains, and are fruitful at 3 years.

The cardamom harvest begins in October and continues for 2–3 months. The fruits do not ripen simultaneously, and therefore require much attention in plucking, while it is necessary to guard against their being eaten by snakes, frogs, and squirrels, and to gather them before the capsules have split. For perfection, the fruits require a short drying after collection, either by sun-heat or gentle fire-heat. They are esteemed in proportion to their plumpness and heaviness, and the sound and mature condition of their seeds, which should form about ¾ of the weight. The Indian kind measure $\frac{4}{10}$–$\frac{9}{10}$ in. long, the Ceylon 1–2 in. The approximate London market values are:—Malabar, good, 6*s.*–9*s.* 6*d.* a lb., inferior, 2*s.*–7*s.* 6*d.*; Aleppy, 2–9*s.*; Madras, 1*s.* 6*d.*–7*s.*; Ceylon, 2*s.* 6*d.*–5*s.* 6*d.* In 1872, Bombay exported 1650 cwt., 1055 being for the United Kingdom; and Ceylon, 9273 lb. to the United Kingdom.

Several other kinds of cardamom possess an importance in Asiatic commerce; they are chiefly as follows:—(1) Round or Cluster cardamom (*Amomum Cardamomum*), a native of Cambodia, Siam, Sumatra, and Java, produced in small compact bunches, the fruit being nearly globular and smooth; (2) the Wild, Bastard, or Xanthioid cardamom, or "cardamom seeds," afforded by *A. xanthioides*, a native of Tenasserim and Siam; these are oval and covered with short prickles. These two sorts are the objects of considerable trade between Siam, Singapore, and China, and one of them is probably the kind cultivated by the French settlers in Saigon, where 1350 *piculs* (of 133¾ lb.) were produced in 1880. The shipments from Bangkok in 1871 were 4678 *piculs* (623,733 lb.), all to Singapore and China; and in 1875, 267 *piculs* of "true," and 3267 of "bastard" cardamoms. Hankow imported in 1879, from abroad, 132 *piculs* (of 133⅓ lb.) of superior, 6985*l.*, and 2362 of inferior, 21,732*l.*; and from native ports, 142½ *piculs* of superior, 7534*l.* Shanghai imported in 1879, 327 *piculs* of superior, 3810 of inferior, and 233 of husks. (3) Winged or Bengal cardamom, *morung elachi* or *buro elachi* (*A. aromaticum*), is produced in the Morung Mountains, in about 26° 30′ N. lat. (4) Nepal cardamoms, from *Amomum subulatum*, are grown on well-watered hill-slopes, under shelter of trees, on the frontiers of Nepal, near Darjiling, and exported to other parts of India. (5) Java cardamoms are produced by *A. maximum* in that island; these are of a brown colour, and more or less furnished with winged longitudinal ridges. (6) Korarima cardamoms are yielded by *Amomum Korarima* (*Cardamomum majus*), an undescribed plant indigenous to the whole mountain region of E. Africa, from Uganda to the countries of Tumhé, Guragne, and Shoa, lying S. and S.-E. of Abyssinia. They are carried to Baso (10° N. lat.), and thence to Massowa, for shipment to India and Arabia. They are of a brown colour, 1½–2 in. long, ¾ in. diam. below, oblong, pear-shaped, and slightly furrowed.

The essential oil afforded by cardamoms is described on p. 1419; they are also capable of yielding as much as 10 per cent of a fatty oil.

Cassia (Fr., *Casse*; Ger., *Cassia*).—The bulk of the spice known as cassia, or "Chinese cinnamon" as it is frequently called on the Continent, is produced by an undescribed tree of S. China, chiefly growing in Loting and Luehpo (in Kwangtung province), Taiwao (in Kwangsi), and in Kweichow, and found in about 19° N. lat. in the forests of the Le Ngum valley, on the left bank of the Mekong, near the Annam frontier. The tree is generally referred to as *Cinnamomum* [*Cassia*] *aromaticum*. It is said to grow with little attention in situations unsuited to other crops. The bark of the tree, forming "cassia lignea," occurs in small bundles about 1 ft. long and 1 lb. in weight, bound up with split bamboo. It has been stripped off the tree by running a knife along each side of the branch, and gradually loosening it; it is then allowed to lie for 24 hours, undergoing a sort of fermentation which permits the epidermis to be easily scraped off, the bark soon drying into the form in which it appears in the market. The quills bear a close resemblance to cinnamon (see pp. 1805–7), but are less uniform and less carefully prepared. They are thicker and harder than cinnamon, and rarely consist of more than two quills, one rolled in the other. There is no doubt that the powdered bark is very largely substituted for the higher priced cinnamon, discrimination between them being a matter of some difficulty. The most reliable tests yet made known for their distinction are given by Hehner, in a paper read before the Society of Public Analysts, Nov. 19, 1879, the main deductions from his observations being:—(1) The proportion of ash in cinnamon is pretty constant (4·59–4·78 per cent.), cassia lignea giving much less (1·84), and cassia vera nearly the same as cinnamon (say 4·08); (2) the amount of ash soluble in water is 25·04–28·98 per cent. in whole cinnamon, about 18 in chips, 8–15 in cassia vera, and 26–40 in cassia lignea; (3) the proportion of oxide of manganese is never more than 1 per cent. (0·13–0·97) in cinnamon, but over 1 (1·13–1·53) in cassia vera, and 3·65–5·11 in cassia lignea; (4) the cinnamon ash is always white, or nearly so, while both the cassia ashes are grey or brown, and yield abundance of chlorine on heating with hydrochloric acid. The young branches of the tree affording cassia lignea are collected and tied up in fagots, constituting cassia twigs, which are a large article of local commerce. The immature fruits of the same tree are believed to form the cassia buds of English trade. Cassia vera or wild cassia is an inferior kind of cassia lignea. The approximate London market values of the spice are:—Lignea, 36–60*s.* a cwt.; vera, 22–46*s.*; buds, 49–72*s.* Our imports of cassia bark (lignea) fluctuated from 1,408,021 lb. 1856, to 283,869 in 1861, 1,117,909 in 1865, 349,349 in 1866, and 875,991 in 1870; since then, it has not been specified in the Returns. In 1878, London received 3,500,000 lb. Hamburg usually imports about 2,000,000 lb. annually direct from China, besides large quantities indirectly. The shipments from Canton, whence it is chiefly exported, had grown from 13,800 *piculs* (of 133⅓ lb.) in 1864, to 96,778¼ *piculs* in 1879. In the same year, Pakhoi despatched 3018*l.* worth; and Shanghai, 124½ *piculs* of buds, 3234½ *piculs* of lignea, and 4467¼ *piculs* of twigs. The twigs are mainly an article of local consumption. In 1872, Canton shipped 456,533 lb. of them to other Chinese ports. In 1879, Hankow imported from foreign ports, 1387 *piculs* of lignea, 8773*l.*; and from native ports, 128¾ *piculs* of buds, 381*l.*, 1182½ of lignea, 7479*l.*, and 3990¾ of twigs, 3442*l.* The trade in buds has decreased, the exports from Canton having fallen from 400 *piculs* in 1848, to 233 in 1866, and 165 in 1867. Our imports of them in 1870 were 29,321 lb.; Hamburg received 1324 cwt. in 1876.

Several other non-Cingalese species of *Cinnamomum* afford kinds of cassia bark in their respective localities. In the Khasia mountains of E. Bengal, the barks of three species (*C. obtusifolium*, *C. pauciflorum*, and *C. Tamala*), growing wild at 1000–4000 ft., have recently been collected and brought down to Calcutta. At least part of the cassia bark of S. India is produced by *C. iners*, possibly only a variety of the true cinnamon (*C. zeylanicum*), found in India, Ceylon, Tavoy, and the Indian Archipelago; the fruits are also gathered in some districts of S. India, but are much inferior to Chinese buds. *C. Tamala* extends into Silhet, Sikkim, Nepal, Kumaon, and even Australia. The Archipelago produces two species, *C. Cassia* and *C. Burmanni* var. *a. chinense*, both said to be cultivated in Java. Padang (Sumatra) exported 6127 *piculs* (817,066 lb.) of the bark in 1871; and Cadiz imported 93,000 lb. from the Philippines in the same year.

According to Low, the *kulit lawang* of Borneo is the aromatic bark of a wild species of "cinnamon," and is produced in abundance in all parts of the island. It much resembles the true cinnamon of Ceylon. A recent writer on the Indian Archipelago (Moore) states that "cinnamon" is the most costly product of Cochin China, and is an uncultivated article. It has a very pungent taste, and is far more aromatic than that of Ceylon. There are several qualities of it, some of which bear a most exorbitant price, and are solely appropriated for the royal use. The outer rind is never removed from it, and it is consequently much thicker than Ceylon cinnamon. It is in high demand among the Chinese, who export large quantities, and prefer it to the best cinnamon of Ceylon. Possibly it is this particular kind which is meant in the Consular Returns for Shanghai for 1879, where an export of 50½ *piculs* (of 133⅓ lb.) of "cinnamon" is stated, in addition to the figures relating to cassia. Hanbury and Flückiger doubtfully refer this thick "cinnamon," or more properly cassia, to *C. Cassia* and *C. Burmanni* var. *a. chinense.*

The essential oil of cassia is described on p. 1419.

Chiretta or Chirayta.—This condiment consists of the entire plant of *Ophelia Chirata* [*Gentiana Chirayita*] collected when the capsules are fully formed, and tied up in flattish fagots, 3 ft. long and weighing 1½–2 lb., with bamboo slips. The plant inhabits the mountainous districts of N. India, from Simla through Kumaon to the Murung district in S.-E. Nepal. It is much used in India, and somewhat in England as a tonic bitter, and substitute for gentian in cattle-foods. An inferior variety, *Ophelia angustifolia*, is sometimes mixed with this drug as found in English commerce. It is less bitter, and is distinguishable by the absence of pith, and by the more woody stem.

Cinnamon (Fr., *Cannelle de Ceylan*; Ger., *Zimmt*, *Ceylon Zimmt*, *Kaneel*).—True cinnamon, with which cassia is often confounded, is produced by *Cinnamomum zeylanicum*, a small evergreen tree of many varieties, distributed through the forests of Ceylon up to 3000 and even 8000 ft. The quality of the bark varies exceedingly with local conditions, some being so inferior as to be collected only for purposes of adulteration. The culture of the best kind seems to be restricted to a strip of country 12–15 miles broad on the S.-W. coast of Ceylon, between Negumbo, Colombo, and Matura, up to an elevation of 1500 ft. A sandy soil is generally selected, but others may be chosen, such as a mixture of sandy with red soil, free from quartz, gravel, or rock; also red and dark-brown soils. Such land in a flat country is preferable to hilly spots. A rocky and stony subsoil is not adapted, as the trees would neither grow fast, nor yield a remunerative return. In making a plantation, the whole of the ground should be cleared, leaving a few trees 50–60 ft. apart. The felled trees should be well lopped, burned, and cleared away. The stumps and roots, after burning, may be allowed to remain, in order to save expense of carriage, merely observing some degree of order in their disposition, by forming regular rows. Holes are dug 8–10 ft. apart and 1 ft. sq.; the distance between the plants depends upon the nature of the soil: the poorer the soil, the nearer should the trees be planted, and *vice versâ*. Should the holes be intended for cinnamon roots, or stumps, the latter must be carefully removed with as much earth as can be carried up with them, and placed in the holes, taking care not to return the earth removed originally in digging the holes, but filling them with the soil scraped from the surface, which has been previously burned, exposed, and formed into manure. Should no rain fall after placing the roots in the holes, the stumps are well covered, and watered morning and evening, until the sprouts shoot out fresh buds, which will be in a fortnight or so from the time of transplanting; watering may then be discontinued. In a month, the new shoots will be 3–4 in. high, much depending upon the weather. If the holes be intended for young plants or seedlings, the latter are removed with boles of earth from the nurseries, and placed in the holes, taking the same care as with the stumps, both in watering and covering, in the event of its being dry weather. The coverings should not be removed until the plant throws out a new pair of leaves from the buds, which is a sign of their having taken root. When a plantation is formed of old stumps, all the branches are cut down to within 6 in. from the ground; this should be done with one stroke of a sharp instrument, in order to avoid the splitting of the stem. From these stumps, cinnamon may be cut and peeled in 12–18 months from the time of transplanting. From seedlings, no crop can be expected before 2–3 years from the date of the transplanting, when there will be but single trees. These, when cut down as already observed to 4–6 in. above the ground, ought to be covered with fresh earth gathered from the space between the rows, and formed in a heap around the base. The next crop will be 3–4 times as much as the first, from the number of sprouts the stem will throw out, and so on every year, the crop increasing according to the number of sprouts each stem will throw out yearly from the cuttings. In the course of 7–8 years, the space left between the rows will only admit the peelers and weeders, as the branches from opposite bushes will almost touch each other. The plantation must be kept clean and free from weeds. Cinnamon requires no manuring; but when weeding, the roots of the bushes should be covered and heaped up with the surface soil, this being done as soon as the cinnamon sticks are removed for peeling. The plantation requires weeding 3–4 times a year during the first 2–3 years, then twice a year will answer the purpose.

For the nursery, a space of ground is selected in rich soil free from stones. The whole brushwood is cleared, leaving only the large trees for shade; all stumps, stones, and roots are removed, and the place is well dug 6–8 in. deep, and formed into long beds 3–4 ft. wide; the seeds are sown 9–12 in. apart, and shaded at 8–12 in. above the ground by a *pandal* of leaves; they are watered on alternate days until they have one pair of leaves, and the watering is continued in very dry weather; but the shade is not removed until the plants are 6–8 in. high, and can bear the sun. These seedlings will be ready for transplanting 3 months after the time when they were sown. Nurseries are made just before the close of the year. When this is done first, the land is prepared during the dry season, from December to March, both inclusive. April sets in with heavy rain generally in Ceylon, and the weather continues wet till September–October. The cinnamon seeds are gathered when fully ripe, and heaped up in a shady place; the outside red pulp then rots and turns quite black, allowing the seeds to be trampled out or otherwise freed from the decomposed pulp; the seeds are well washed in water (just as is done to cherry coffee, before making into parchment in the white shell, see pp. 702–3), and dried in the air without exposure to the sun. Seeds that float on the surface of the water should be rejected. The quality of the bark depends upon its situation on the branch: that peeled from the middle of the bush or branch is the best or "1st" sort; that taken from the upper end, the "2nd"; while that obtained from the base of the branch, or the thickest end, is called "3rd" sort. The peeling process commences early in May, and continues until late in October. When a Chilaw perceives a shoot of a proper growth, he strikes a small bill-hook (*catty*) obliquely into the shoot, and gently opens the gash to discover whether the bark separates freely from the wood; should this not be the case, he leaves the sucker for a future time. Some shoots never arrive at a fit state for decortication. Those which are cut are usually $\frac{1}{2}$–$\frac{3}{4}$ in. diam., and 3–5 ft. long. They are tied in bundles, and carried to sheds appropriated to the preparation of the cinnamon.

Being cleared of small shoots and leaves, two longitudinal slits are made in the bark, which is gradually loosened by the convex side of a peculiar knife (*mama*), and then usually half the circumference of the bark comes off in one entire slip. When the bark adheres firmly to the wood, it is strongly rubbed with the handle of the peeling-knife, until it is disengaged and stripped off. The sections of the bark thus obtained are carefully telescoped one into the other, collected into bundles, and firmly pressed or bound together. In this state, they remain for 24 hours, or more, thereby facilitating the subsequent removal of the cuticle. The interior side of each section of bark is placed on a convex piece of wood, and the epidermis, together with the greenish pulpy matter immediately under it, is carefully scraped off by a curved knife. This is an operation requiring some nicety, for if any of the outer bark be allowed to remain, it gives an unpleasant bitterness to the cinnamon. In a few hours after the removal of the cuticle, the pieces are put one into the other till they form almost solid sticks about 40 in. long. On the first day, they are suspended under shelter upon open flat forms; on the second day, they are placed on wickerwork shelves, and exposed to the sun. When sufficiently dry, they are made up into bundles of about 30 lb. each, which, previous to shipment, are subjected to a process of assortment. For export to Europe, the bark of large shoots or thick branches, producing coarse cinnamon, and that of very young and succulent shoots, possessing little flavour, is rejected, and used for the preparation of the essential oil (see p. 1419).

The cinnamon-gardens of Ceylon had increased from 14,400 acres in 1860–4, to 26,000 in 1878. It is still being extensively planted upon nearly worn-out coffee estates, and upon other land considered unpromising for more valuable crops, and the results are said to be satisfactory. The exports from the island have fluctuated considerably, having been 776,675 lb., 38,833*l.*, in 1864, 2,685,395 lb., 134,270*l.*, in 1869, 1,132,191 lb., 53,077*l.*, in 1874, and 1,665,481 lb., 78,069*l.*, in 1878. The London market values of Ceylon cinnamon are:—1st quality, 1*s.*–3*s.* 6*d.* a lb.; 2nd, 11–28*d.*; 3rd, 7–21*d.*; 4th, 7–18*d.*; chips, 1¼–6½*d.*

The peculiar tendency of cinnamon to deteriorate in new localities, coupled perhaps with the absence of due care and experience, has rendered it impossible to produce the spice equal to the Cingalese article anywhere outside that island. It is most nearly approached by that grown in S. India, known as "Malabar," "Tinnevelly," or "Tellicherry," and valued at 1*s.* 5*d.*–2*s.* 4*d.* a lb. In the Seychelles, are said to exist 2000 acres of cinnamon shrubs, which are utilized solely as firewood. In Dominica also, the plant is found commonly in a wild state. Brazil and French Guiana afford insignificant quantities of a very inferior cinnamon. But Java occupies an important position as a producer of this spice. The culture and preparation do not differ essentially from the methods practised in Ceylon, but the packing is usually effected in wooden cases, and black pepper is said to be sprinkled among it to preserve the flavour. The exports from Java in 1879–80 were:—638 *piculs* (of 135½ lb.) to Holland, and 24 to Australia.

Our imports of cinnamon in 1880 were:—1,377,272 lb., 91,544*l.*, from Ceylon; 189,548 lb., 8213*l.*, from other countries; total, 1,566,820 lb., 99,757*l.* Our re-exports in 1880 were 1,172,166 lb., 78,805*l.*, chiefly to Spain, Germany, Mexico, and Holland.

Other *Cinnamomum spp.*, and the means of distinguishing cinnamon from cassia, are described under the latter (pp. 1804–5).

Cloves (Fr., *Girofles*, *Clous de Girofles*; Ger., *Gewürznelken*).—The name cloves is applied to the dried flower-buds or calyces of *Eugenia caryophyllata* [*Caryophyllus aromaticus*], an evergreen tree of 30–40 ft., indigenous only in the five small islands constituting the Moluccas proper (Tarnati, Tidor, Mortir, Makian, and Bachian), but introduced at various times into, and more or less widely cultivated in, Amboina, Haruku, Saparua, Nusalant, Sumatra, Penang, Malacca, Mascarene Islands, Réunion, Mauritius, Zanzibar, Pemba, Jamaica, Dominica, and French Guiana.

In cultivating cloves, the mother-cloves (fruits) are planted in rich mould about 12 in. apart, screened from the sun, and duly watered. They germinate within 5 weeks, and, when 4 ft. high, are transplanted at distances of 30 ft. There should be a certain amount of sand in the soil to reduce its tenacity, and less manure is required than for nutmegs. The tree naturally selects a volcanic soil, and a sloping position. The yield commences at about the 6th year, and is at its maximum in the 12th year, when the average annual produce may be estimated at 6–7 lb. of marketable fruit from each tree. There is usually a crop every year, but in Sumatra, the trees often bear only twice in 3 years. When past its prime, the tree has a ragged appearance. Its existence in Sumatra is supposed to be limited to a duration of about 20 years, except in very superior soil, when it may perhaps last 24 years; yet in Amboina, it does not bear till the 12th–15th year, and continues prolific to the age of 75–150 years. Hence, it is necessary to plant a succession of seedlings when the old trees have attained their 8th year, this octennial system being adhered to throughout. The slight hold which the trees have upon the soil, renders it very desirable that they should be provided with shelter from strong winds. With this object, the plantations in Sumatra are belted with a double row of *Casuarina littorea* and *Cerbera Manghas*. Similar precautions in Zanzibar and Réunion would probably have mitigated the havoc recently created by hurricanes among their clove-gardens. The harvesting of the flower-buds (cloves) commences immediately they assume a bright-red colour. The best and most usual plan is to pluck them singly by hand, movable stages facilitating the operation in the case of the upper branches. Sometimes, however, they are beaten off by long bamboos, and caught in cloths spread below. The plucked cloves undergo a process of drying, which confers a brown hue, and prepares them for packing. In Sumatra, simple exposure to the sun for several days on mats is the common method; but elsewhere they are occasionally also smoked on hurdles covered with matting near a slow wood fire; and very rarely they are scalded in hot water before smoking. They are ready for packing when they break easily between the fingers.

The production of cloves fluctuates enormously. The Moluccas, or rather the four of them where the tree is cultivated (Amboina, Haruku, Saparua, and Nusalant), produced 869,727 Amsterdam lb. (of 2·2 lb.) in 1846, but only 89,923 in 1849; in 1854, Nusalant harvested 120,283 Amsterdam lb. from 13,042 trees (an average of 9 lb. a tree), Saparua 181,137 from 29,732 trees, Haruku 38,803, Amboina 170,689; total, 510,912 Amsterdam lb. Java exported only 92 *piculs* (of 135½ lb.) in 1879–80; but in 1878–9, the figures were 1614 to Holland, 5 to Sweden, 3 to America, and 1237 to Singapore, total 2859 *piculs*. Of late years, the islands of Zanzibar and Pemba on the E. African coast, have been the chief producers of cloves, yielding a maximum annual crop of 10½ million lb. before the disastrous hurricane of 1872. The clove-gardens of Pemba, situated mostly on the W. side of the island, escaped the destruction which befel the larger island. The exports from these two islands go largely to Bombay, also direct to America and Hamburg, smaller quantities reaching the Red Sea ports by native craft. For European and American markets, the packages used are mat bags made of split coco-nut leaves; for native ports, simply raw hides. The Bombay imports were 45,642 cwt. in 1869–70, 20,968 in 1870–1, 43,891 in 1871–2, 25,185 in 1872–3. Réunion in 1825–49 produced yearly as much as 800,000 *kilo.* (of 2·2 lb.), but has recently suffered much from hurricanes; the crop of 1879 was destroyed by a cyclone, and the exports for 1879 (8777 *kilo.*) were merely re-exports from St. Marie de Madagascar. In Jamaica and Dominica, cloves flourish remarkably, and are eminently suited for cultivation with nutmegs by small proprietors on the hills. Our imports in 1870 were 1,089,667 lb., 16,374*l.*; there are no specific returns since. We received 3271 cwt. from Bombay in 1872–3. Hankow, in 1879, imported 256½ *piculs* (of 133⅓ lb.) of cloves, 4056*l.*; and 30 *piculs* of mother-cloves, 438*l.* The cloves of commerce vary in plumpness, brightness of tint, and yield of essential oil. The values of the chief kinds met with in the London market are:—Penang, 20–29*d.* a lb.; Amboina, 16–23*d.*; Zanzibar, 14–19*d.*

Clove-stalks, the *vikunia* of the natives, are largely shipped from Zanzibar, and used in the manufacture of mixed spice and for adulterating ground cloves. They yield 4–6½ per cent. of volatile oil. Mother-cloves or fruits are also exported, probably for a similar purpose. In one drug sale in 1873, 4200 packages of the former were sold at 3–4*d.* a lb., and 1050 bags of the latter at 2–3*d.* a lb. The microscope will reveal the stone-cells of the stalks and the large starch-granules of the fruit, as well as both stone-cells and starch-granules if pimento has been fraudulently added.

The essential oil of cloves is described on p. 1420.

In Brazil, the flower-buds of *Dicypellium caryophyllatum*, whose bark furnishes clove cassia, are used as substitutes for true cloves.

Coriander (Fr. *Coriandre*; Ger. *Koriander*).—Coriander-seeds are the produce of *Coriandrum sativum*, a small plant now found growing as a cornfield weed in many temperate and tropical countries. It is cultivated in the E. counties of England, especially Essex, and in various parts of the Continent; it is also produced in India and N. Africa. In the Dutch E. Indies, a larger and more oval variety is met with. In England, under the name of "col," it is sometimes sown with caraway, and gathered in the first year, while the caraway is left on the ground till the following season. The seedlings are hoed out so as to leave rows 10–12 in. apart. Harvesting is performed with sickles, and the dry seed is threshed out on a cloth in the field, an average crop being 15 cwt. an acre on the best land. In 1872–3, Sind exported 948 cwt., and Bombay 619 cwt., while Calcutta shipped 16,347 cwt. in 1870–1. Corianders are mostly used for flavouring gin, and in the manufacture of curry-powder.

The essential oil is described on p. 1420.

Cumin. See Drugs, pp. 809–10.

Galangal or Galingale (Fr., *Galanga*; Ger., *Galgant*).—The galangal root now met with in European commerce is the rhizome of the lesser or Chinese plant (*Alpinia officinarum*), cultivated in Hainan Island, S. China, and probably also in some of the adjacent mainland provinces, while the greater or Java galangal (*A. Galanga*) is rarely seen amongst us. In E. Europe, particularly Russia, it is used as a spice, for flavouring tea and liqueurs, and in cattle medicine. Shanghai exported 370,800 lb., value 3046*l.*, in 1869; and Kiungchow, 2113 *piculs* (281,733 lb.) in 1877, and 5661½ *piculs*, 2194*l.* in 1879, the latter stated officially to come entirely from the mainland opposite. It is of a dark-brown colour, and powerfully pungent.

The essential oil is described on p. 1421.

Gentian (Fr., *Gentiane*; Ger., *Enzian*).—Gentian is the dried root of *G. lutea*, a native of open grassy places on the mountains of Central and S. Europe, as far north as the Suabian Alps, near Würzburg. The roots of several other species are sometimes collected and mixed with it, viz.:—(1) *G. purpurea*, found in meadows on the Apennines, in Savoy, Switzerland, Transylvania, and S.-W. Norway, and a variety in Kamschatka; (2) *G. punctata*, indigenous to the Alps of S.-E. France, Savoy, S. Switzerland, extending E. to Austria, Hungary, and Roumelia; (3) *G. pannonica*, met with only on the mountains of Austro-Hungary. *G. Catesbœi* [*Saponaria*] is gathered for home consumption in the United States. The roots are collected and dried. Our supplies come mostly from Germany, but partly also from Marseilles. Our imports in 1870 were 1100 cwt. In England, it is used medicinally (see p. 811), but principally as an ingredient of cattle-foods. In Bavaria and Switzerland, advantage is taken of its 12–15 per cent. of uncrystallizable sugar to make from it a liquor known as *Enziangeist* or "gentian-spirit."

Ginger (Fr., *Gingembre*; Ger., *Ingwer*).—Ginger is the dried rhizome, either scraped or unscraped, of *Zingiber officinale* [*Amomum Zingiber*], a reed-like plant indigenous to Asia, and universally cultivated in the warmer parts, but not known wild; now to be found also in the W. Indies, S. America, Tropical W. Africa, and Queensland.

In Jamaica, propagation is effected by division of the root, the pieces being planted in well cleared and trenched land in March–April, flowering in September, and fading towards the end of the year; when the stems are quite withered, generally about January, the roots are dug up, picked, cleaned, gradually scalded in boiling water, sun-dried for several days, and packed, forming "hands" or "races" of so-called "coated" (i. e. not deprived of epidermis) ginger. Jamaica had 227 acres under this crop in 1875–6, and 144 in 1877–8. The exports from the island were 1,261,873 lb. in 1869, only 599,766 in 1871–2, 1,613,764 in 1875–6, and 908,603 in 1877–8. The London market values of Jamaica ginger are approximately 4½–12*l.* a cwt. for fine, and 2¼–5¼*l.* for ordinary to good. Formerly Barbados and Hayti used to grow ginger in considerable quantity; but the latter now exports none, and the shipments of green ginger from the former were valued at only 56*l.* in 1877, and 41*l.* in 1878. Our imports from the British W. Indies were 15,594 cwt. in 1876.

Little is known about the production of ginger in Sierra Leone. In 1868, the value of the export was 18,917*l.*; in 1869, 14,008*l.* Our direct imports were 6612 cwt. in 1878, and 11,951 in 1879. About half the produce comes to England, and the other half goes to America. The London market value of African ginger is only about 18–25*s.* a cwt.

The cultivation of ginger in India extends from the Himálayas to Cape Comorin. In the Hill States, the best "races" of the previous year are smeared with cow-dung and placed in a corner where they will not dry up. After the first rain, the land is ploughed 2–3 times, and divided into little beds which will shed the water readily. Root-sections are then planted 3 in. deep and 9 in. apart, and covered with dead leaves and ½ in. of manure. Watering is resorted to in the dries. When the plants are about 2 ft. high, the rhizomes are dug up, buried for a month, sun-dried for a day, and are ready for use. To get it into *sonth*, or keeping condition, the fresh rhizomes are shaken in a basket for 2 hours daily for 3 days, then sun-dried for 8 days, and again shaken. Thus the outer skin is removed, and 2 days' further drying finish it for the market. In Dacca, the natives cleanse the roots by boiling lime-water. In Mysore, a red soil free from stones is considered best; between 11 April and 11 May, the ground is hoed, and made into ridges 18 in. broad, 18 in. high, and 18 in. apart, with perpendicular sides; two rows of cuttings are put into each ridge, slightly covered with earth, and protected by a screen of bushes. Between mid-June and mid-July, the shoots appear, and 10 days later the bushes are replaced by small twigs, and weeding is done by hand. About mid-December to mid-January, the roots are fit for pulling. Those intended for replanting are mixed with a little red mud, and immediately buried in a pit; those intended for sale are deprived of the outer skin by scraping with a knife, sprinkled with the ashes of burnt cow-dung, and dried on mats for 8–10 days. Our imports of E. Indian ginger were 7472 cwt. from Bombay and Sind in 1877, increased to 25,781 cwt. in 1879; 7202 cwt. from Madras in 1877; 16,470 cwt. from Bengal in 1878. The London market values are about 16–22*s.* a cwt. for Bengal, and 23–125*s.* for Cochin.

Much ginger is grown in China, and considerable quantities of the young succulent rhizomes preserved in syrup are sent to this country. Our imports were 9372 cwt., 25,722*l.*, in 1872, and 6996 cwt., 19,894*l.*, in 1875. The Venezuelan port of Ciudad Bolivar shipped 450 lb. to New York in 1878; and Panama exported 98*l.* worth to the United States in 1879.

"Scraped" or "uncoated" (decorticated) ginger is often bleached by subjection to the fumes of burning sulphur, or by immersion in chloride of lime solution, while much is washed over with either sulphate or carbonate of lime. Our total imports in 1880 were from:—Bombay and Sind, 23,249 cwt., 45,828*l.*; Madras, 12,492 cwt., 25,460*l.*; British W. Indies, 5639 cwt., 28,624*l.*; Bengal and Burma, 3617 cwt., 3713*l.*; W. Africa, 3142 cwt., 3000*l.*; other countries, 1823 cwt., 2920*l.*; total, 49,962 cwt., 109,545*l.* The total figure for 1876 was 62,164 cwt. Our re-exports in 1880 were 18,086 cwt., 32,152*l.*, chiefly to Germany, the United States, and Australia.

The essential oil is described on p. 1421.

Mustard (Fr., *Moutarde*; Ger., *Senf*).—Black mustard is the seed of *Brassica* [*Sinapis*] *nigra* and white mustard that of *B.* [*S.*] *alba*, while Indian mustard, brown mustard, or *rai* is afforded by *B.* [*S.*] *juncea*, and is sometimes offered in London sales for black mustard. *S. glauca* and *S. ramosa* also yield a white mustard-seed in India.

The first species is found wild in all but the most northern parts of Europe, as well as in N. Africa, Asia Minor, Mesopotamia, the Caucasus, W. India, S. Siberia, China, and naturalized in N. and S. America. It is cultivated extensively in Alsace, Bohemia, Holland, Italy, and on the richest alluvial soils in England, notably in Lincolnshire and Yorkshire. The great aim of the grower is to produce reddish-brown seed, without any intermixture of grey, which is attributed to rain during the ripening, and greatly lowers the value of the parcel. The crop requires very little tillage. A shallow furrow is ploughed, and the seed is sown broadcast, at the rate of 1 bush. an acre, in April, the harvest taking place in June–July following. The land is generally sufficiently seeded to produce a 2nd crop, which is sometimes gathered within the same year. A yield of 40 bush. an acre is not uncommon. The French departments of Nord, Pas de Calais, Bas-Rhin, and Charente annually produce about 650 tons, value 6000*l.*, while the whole production of France in 1867 was stated at 3000 tons.

The second (white) species belongs rather to S. Europe and W. Asia, but its cultivation is extending in England, where it is grown as an agricultural crop in Essex and Cambridgeshire. It is much less remunerative than black mustard.

The third species is extensively cultivated in India, Central Africa, and other tropical countries. It flourishes particularly well in the saline soils of S. Russia and the steppes lying N.-E. of the Caspian, some 800 tons of seed being annually prepared for table at Sarepta, in the government of Saratov.

The mustard flour which constitutes the domestic spice is prepared from the seeds crushed between rollers, pounded, sifted, and re-sifted into 3 qualities, "superfine," "fine," and "seconds." Only the seeds of the black and white species are supposed to be employed; but it is exceedingly probable that much of the third kind finds its way into the composition, as flour, turmeric, and capsicums are known to do in the lower grades of the article. Characteristic tests by which white and black mustard-seeds may be distinguished are:—(*a*) The aqueous extract of white mustard soon acquires a powerful odour of sulphuretted hydrogen, while the black smells only of the pungent oil; (*b*) the aqueous extract of the former is coloured deep blood-red by ferric chloride solution.

British India exported 1418 tons of mustard-seed in 1871–2, 790 tons going to the United Kingdom, and 516 to France; in 1876, the total figure was 12,770 cwt.; in 1879, only 5016 cwt. Nicolaieff (Russia) exported 498 quarters (of 8 bush.) in 1879.

The fixed and volatile oils of mustard-seed are described respectively on pp. 1396, 1424.

Nutmegs and Mace (Fr., *Muscades et Macis*; Ger., *Muskatnüsse und Muskatblüthe*).—The fruit of *Myristica fragrans* [*moschata, officinalis*], somewhat resembling a small round pear, contains a single seed, the kernel or nucleus of which forms the "nutmeg" of commerce, while its fleshy crimson envelope (*arillus*) is called "mace." The tree is a bushy evergreen of 40–50 ft., found wild in the Banda Islands, Damma, Amboina, Ceram, Bouro, Gilolo (Halmahera), the W. peninsula of New Guinea, and in many neighbouring islands, but not indigenous westward of these, nor to the Philippines. It has been introduced with varying success into Bencoolen (W. Sumatra), Malacca, Bengal, Singapore, Penang, Brazil, the W. Indies, French Guiana, and Réunion; but the Banda Isles remain the chief nutmeg-garden of the world. Of these islands, three are planted with the trees, viz. the Great Banda or Lonthoir, Banda Neira, and Pulo Aai. There are in all 34 parks, containing 319,804 bearing trees. The total produce from these yearly is about 4000 *piculs* (of 139½ lb.) of nutmegs, and 1000 of mace; this gives little more than 1½ *catti* (of 1·39 lb.) of spice for each tree per annum, but then a very large proportion of the produce is lost from the following causes: much cannot be collected from the height of the trees, and the inaccessible places in which hundreds of them are placed, and much is lost by wind-falls; a large pigeon called *walur* feeds extensively upon the fruit, and ejects it after digesting the mace; besides these, field-rats eat the nuts. The distribution amongst the islands is in the following proportions: Great Banda, 25 parks; Neira, 3 parks; Pulo Aai, 6 parks. The chief labour is performed by convicts furnished by the Dutch Government, there being no indigenous population in Banda.

The only attempt at cultivation is the cutting close with long knives the ferns and grass below the trees. There does not appear to be that tendency to the growth of weeds and underwood that exists so strongly in the Straits, to the great detriment of the planters. No manure or artificial stimulus is used; the plants deposited abundantly by the pigeons are merely taken up and stuck in wherever a vacancy occurs, therefore no regularity is observed. In some places, clumps of trees are growing together not more than 10–12 ft. apart, all growing without exception under the shade of the *canari* (*Canarium commune*). The nutmeg cannot be said to be cultivated in Banda: it is merely collected. It has occupied its present position there from time immemorial.

With regard to the differences that exist between the Banda trees and those of the Straits, the first remarkable feature is their respective heights. The tree of the Straits is a mere shrub compared with that of Banda, where 50–60 ft. is no uncommon size. It would appear that the shading is overdone in the Straits, at the same time, owing to the strong winds that constantly prevail, the tree needs shelter of some description. The tree as a general rule does not bear fruit before the 8th or 9th year, and is not considered in its prime until about 25 years old; it is said to bear well up to 60 years, and even longer. The male tree is much shorter lived than the fruit-bearing one. The parkineers in the Bandas do not estimate the proportion of males above 2 per cent.; if this be the case, there are far too great a number in the Straits plantations. With respect to the proportion of males and females yielded by a given number of planted seeds, the parkineers say they never get more than 30 per cent. of males, and seldom so many; this again is far better than Straits planters can boast of. The Banda fruit hangs upon longer and more slender stalks than the Straits, the skin is more free from all blemish, more thin relatively to the fruit, and of more uniform proportion. The black spot or gangrene of the outer covering exists among the Banda plantations, but in so slight a degree that but little account is taken of it. It is caused by an insect depositing its larvæ in the husk; they feed on the saccharine matter of the outer covering, until it bursts, when they make their way into the soft nut itself, and become the small weevil so well known to all planters. The Banda nuts frequently split before maturity, as in the Straits; this is produced by similar causes,—cold, damp weather, and sudden changes of temperature. The Banda trees bear more or less every month throughout the year, but there are four months in which the crop is four or five times its usual quantity, these are May, June, September, and October. The Banda method of collecting the fruit is far better than that adopted in the Straits. They use neatly made oval baskets of bamboo, open for half their length on the upper side, with a couple of prongs projecting from the top; these seize the fruit-stalk, and, by a gentle pull, the nut falls into the basket, which is capable of containing three or four nutmegs. Thus the mace is not spoiled or bruised by falling on the ground, and there is no searching about the grass for the escaped nut.

The Banda manner of breaking them when dried is also superior. This is done by spreading them on a sort of drumhead, and striking them with flat pieces of board. Several are cracked at each stroke, swept off, and resupplied as fast by a man standing alongside. One man in this way will break more nuts without injury than half a dozen men after the Straits fashion. Women and children are employed in the collection of the produce, which is brought in twice a day. The mace is removed by scraping with large knives from the base, and is probably not a little injured by the operation. The plan of removing it by the hand from the apex is decidedly preferable, as the interlacings of the mace are thus freed, and the blade is better expanded. In Banda, the mace is dried in the sun, and delivered monthly at the Government godowns; the nuts are smoked, in the usual Straits fashion, by slow wood fires, for three months, and delivered quarterly. The mace, when received, is divided into three qualities, and packed in casks containing about 280 lb.; in packing, very slight pressure is used, such as a man standing in the cask and treading down the spice as it is filled in. The nuts, when broken, are packed in wooden bins, filled up with lime and water to the consistency of mortar, where they are allowed to remain for three months, the bins being carefully closed and marked. At the expiration of three months, they are taken out, sorted into three qualities, and packed in casks similar to those used for the mace; these casks are all made of the best Java teak. The refuse nuts are ground down to a fine powder, and converted into "nutmeg-butter," by steaming them over large caldrons for 5 or 6 hours, and compressing the warm mass, packed in bags, between powerful wedges, when a brownish-coloured fluid runs out. This on cooling becomes of a saponaceous appearance and consistence, and is the "nutmeg-butter" or "mace-oil" of commerce. It is further described under Vegetable Fixed Oils, pp. 1396–7.

It should be observed that the Banda method of breaking and liming the nuts, which originated with the Dutch policy of monopolizing the culture by destroying the vitality of the exported nuts, is still widely persisted in, and even necessary to suit the prejudices of certain markets. But our planters in Bencoolen adopted a much simpler plan, and one which did not entail the spoiling of a large proportion of the nuts. It consists in exposing the nuts on frames to the gentle heat of a smouldering fire, with proper ventilation, for 2 months, turning them every 2nd or 3rd day; the shells are then cracked by a wooden mallet, and the assorted nuts are rubbed over with dry lime. Even dry liming is said to be unnecessary, as the nuts keep well in their shells, and are thus imported into Chinese markets; but the weight of the shells adds a third to the cost of freight, which is important in long transport.

The Banda Isles remain the chief source of nutmegs and mace, despite all attempts to establish the culture elsewhere, and the figures show a continuous increase in the exports. The shipments from Java of Banda produce in 1878–9 were:—Nutmegs: 10,475 *piculs* (of 135⅓ lb.) and 7 cases to

Holland, 266 *piculs* to America, 302 *piculs* to Singapore, 78 *piculs* and 11 cases to Port Said, 54 *piculs* to France, 9 *piculs* to England; mace: 2832 *piculs* and 26 cases to Holland, 18 *piculs* to England, 14 *piculs* to Singapore, 10 *piculs* and 6 cases to Port Said. In 1879–80, the figures were:—Nutmegs: 5216 *piculs* to Holland, 61 to France, 1130 to America, 31 to Australia, 777 to Singapore, total, 7215; mace: 1902 *piculs* to Holland, 103 to America, 4 to Australia, 23 to Singapore, total, 2032. The exports from Penang in decennial periods were:—1840, 598 *piculs* (of 133⅓ lb.) nutmegs, 159 of mace; 1850, 2086 of nutmegs, 656 of mace; 1860, 6421 of nutmegs, 2094 of mace. Penang nutmegs have never been limed. Singapore, in 1848, had 1190 acres under nutmegs, containing 71,400 trees, and producing 624 cwt. of nutmegs and 156 of mace. The whole export from the Straits in 1867 was 485,123 cwt. nutmegs, 50,559*l.*, and 5416 cwt. mace, 7354*l.*; the combined total in 1877 was 5323 *piculs* (of 133⅓ lb.); in later years, the figures include all spices except pepper. The nutmeg parks of the Straits have never recovered from the disastrous effects of a blight which attacked them in 1857. The exports from Sumatra were 1952 *piculs* of nutmegs and 403 of mace in 1872; and 2237 of nutmegs and 568 of mace in 1873. The port of Padang alone shipped 284 *piculs* of nutmegs and 28 of mace in 1874; and a total of 2766 *piculs* in 1871. The French island of Réunion exported 5000 lb. of nutmegs and 900 of mace in 1864, and more in 1871, but the culture is declining. The tree succeeds well in the W. Indies, and numbers are to be found under semi-cultivation in Jamaica, Dominica, and Grenada.

Our annual imports of nutmegs amount to 400,000–800,000 lb.; and of mace, 60,000–80,000 lb. The London market values of nutmegs vary with their size, as follows:—78–60 to the lb., 3*s.* 5*d.*–5*s.* a lb.; 90–80, 2*s.* 10*d.*–3*s.* 7*d.*; 132–95, 1*s.* 10*d.*–2*s.* 11*d.* The approximate price of mace is 1*s.*–3*s.* a lb. for 1st quality, and 1*s.*–1*s.* 8*d.* for 2nd and inferior.

The fixed and volatile oils of nutmegs and mace are described respectively on pp. 1396–7, 1424.

Other so-called "nutmegs" which figure very rarely or not at all in commerce are as follows:—American, Jamaican, or calabash (*Monodora Myristica*); Brazilian (*Cryptocarya moschata*); Californian or stinking (*Torreya Myristica*); Madagascar or Clove (*Agathophyllum aromaticum*); long, male, or wild (*Myristica tomentosa* and *M. fatua*), sometimes imported; Peruvian (*Laurelia sempervirens*), used as a spice in Peru; plume (*Atherosperma moschata*); Santa Fé (*Myristica Otoba*), edible.

Pepper (Fr., *Poivre*; Ger., *Pfeffer*).—The name "pepper" is somewhat widely applied. The so-called "Cayenne-" or "red pepper" has been described under Capsicums (see p. 1803). Two species of *Piper* will be found under Drugs, viz. Cubebs (p. 809), and Matico (p. 818); a third falls within the range of the articles on Drugs (Kava-kava, p. 815) and Narcotics (Ava, p. 1305); and two others are dealt with under Narcotics—Betel-pepper, p. 1305. There remain for description as spices, the common black pepper, white pepper, long pepper, and Ashantee pepper.

1. *Black Pepper.*—The plant (*Piper nigrum*) affording black pepper is a perennial climbing shrub, indigenous to the forests of Travancore and Malabar, and cultivated also in Sumatra, Java, Borneo, the Malay Peninsula, Siam, the Philippines, and the W. Indies. Several accounts have been published of the cultivation and harvesting of black pepper; they differ mainly in minor details, and may be summarized as follows.

Where pepper-vines are found already growing, the forest is cleared of underwood, and sufficient trees only are left to provide shade, while permitting free ventilation, 6 ft. apart being considered a proper distance. The vines are trained up to the nearest trees, which are preferably 8–12 in. diam., for convenience in climbing when harvesting the fruit, all kinds of trees being apparently availed of indiscriminately. The root of the vine is manured with a heap of leaves, and the shoots are trained up twice annually. The vines live about 30 years, and are then replaced by others found growing wild around, or systematically planted. The pepper obtained from spontaneous plants is said to quite equal that grown in gardens, while the care necessary is almost nominal. A very wasteful plan sometimes adopted for manuring these natural pepper-plantations consists in setting fire to the trunks of very large trees, which are thus killed, and soon devoured by insects, becoming a heap of rotten dust, which gets washed by the rain around the roots of the vines.

In commencing a new plantation where vines are not to be found growing spontaneously, the first consideration is choice of site. Preference is to be given to level ground bordering rivers or streams, but not subject to inundation; slopes are to be avoided, unless very gentle; and plains will require deep ploughing and much manure. Propagation may be from cuttings and suckers, or from seed. The plants raised by the latter means are said to yield for 14 years, while those from the former are only fruitful for 7 years, but their crops are superior in both quantity and quality, consequently the planting of suckers or cuttings is most generally adopted. The next consideration will be the kind of tree to plant as a support and shade for the vines. Where trees are growing on the ground to be planted with pepper, preference is given to the mango (*Mangifera indica*), whose fruit is not injured by the development of the pepper-vine; failing this, recourse may be had to the jack (*Artocarpus integrifolia*), whose fruit, however, is said to be diminished in quantity and injured in quality by the presence of the pepper. When it is necessary to plant trees, choice is made of the

Erythrina indica, as a large branch of it put into the ground in the rainy season will be capable of supporting the vine in the course of a year; mango-trees may then be raised meantime, as 6–15 years' bearing of the vines suffices to kill the *Erythrinas*. In commencing a plantation upon *Erythrinas*, the ground is usually fenced with a mud wall, and made into terraces. Between mid-July and mid-November, the ground is deeply hoed, and set out with plantains at about 12 paces apart; between the first week in February and first in March, branches of *Erythrina* 6–12 ft. long are planted at 60 paces apart, and watered till the rainy season sets in. Between 10 May and 10 June, the pepper-vines are planted, which may be done in several ways. One plan is to put ½ doz. cuttings each 18 in. long into a basket, which is filled with earth, and buried at the foot of the tree, with the cuttings sloping towards it. Between mid-October and mid-November, the ground around the basket is dug, and the vines are manured with cow-dung and dead leaves. The baskets are said to be a great protection to the plants in their early life, but are often omitted. In either case, during the dry seasons of three years after planting, the vines need watering, in favourable soils, once in 3 days; in dry soils, on alternate days. Between mid-October and mid-November they are manured, and are trained up to the tree till 6 ft. high, after which they are self-supporting. After the 3rd year, the plantains are dug up; and then this manuring and hoeing of the ground is performed twice annually, viz. between mid-October and mid-November, and between mid-July and mid-August. The vines produce in 4–5 years, and are in full bearing in the 6th or 7th, continuing to yield for 12–14 years, when the *Erythrinas* die. In some cases, the trees supporting the vines are pruned, and their branches are lopped; in others, the leaves only are thinned. Mango-trees should be at least 20 years old before having to support the vines.

The Sumatran mode of cultivation differs considerably. The ground is cleared, ploughed, and sown with rice; cuttings of the vine are then planted 5 ft. apart each way, with a sapling of some tree of quick growth and rough bark, in September. The vines are left alone for 12–18 months, then entirely buried, except a small surface of the bent stem, whence spring new shoots, 3–4 of which are allowed to climb the tree planted with them, and are expected to give flowers and fruits a year later. There are two crops annually, the 1st in December–January, the 2nd in July–August; the latter is much inferior in both quantity and quality.

The yield of the plantations varies somewhat according to circumstances. In Sumatra, the dual crop is estimated to average 1½ lb. from each vine per annum. In Malabar, each vine gives a mean of 2 lb. a year up to the 15th–20th year, or about 24 lb. for each tree, which may support 8–12 vines. Sometimes 8–10 lb. is got from a single vine. An acre is reckoned to bear 2500 plants, and to cost not more than 4*l.* to bring into bearing, while yielding a produce worth about 80*l.* when in full bearing. The fruits grow in masses of 20–30 on a single stem. The harvest takes place when they are full-grown and hard, but before they mature, in which latter state they lose pungency and fall off. The season for gathering falls between mid-December and mid-February. The bunches (*amenta*) are hand-plucked in bags or baskets, and the berries (pepper) are then detached from the stem by rubbing with the hands or feet on a mat. The sound berries are then sun-dried for 2–3 days, in a single layer, either on mats or on a patch of smooth ground, being collected in earthen jars at night away from the dew. Mat-drying is said to give a heavier return than ground-drying. The dry pepper is put up in mat bags of 64–128 lb., and is ready for the market.

Our imports of black pepper in 1880 were 21,179,059 lb., 385,108*l.*, from the Straits, and 550,909 lb., 12,979*l.*, from other countries; total, 21,729,968 lb., 398,087*l.* The total in 1879 was only 17,532,958 lb.; in 1877 it was 28,643,635 lb. Our re-exports in 1880 were 12,925,886 lb., 235,801*l.*, chiefly to Germany, Russia, Italy, Holland, and Spain. The fluctuations in our imports from different countries have been as follows:—Java: 2792 lb. in 1876, 74,250 in 1879, none between; Abyssinia: 180,887 lb. in 1876, 0 in 1879, 12,950 in 1880; Siam: 60,000 lb. in 1876, none since; Cochin China: 210,000 lb. in 1876, 0 in 1878 and 1879, 4850 in 1880; Cape: 19,988 lb. in 1876, 180,154 in 1879, 18,642 in 1880; Straits: 27,825,576 lb. in 1877, 16,932,073 in 1879. In the E. Archipelago, pepper-culture is widely spread. It is again assuming large proportions in Atjeh [Atchin or Acheen], the produce being shipped chiefly to Penang and Batavia, Edi on the N.-E. coast (of Sumatra) being the principal mart. In 1822, the Kingdom of Deli had a harvest of 26,000 *piculs*. The country and the people are remarkably adapted to pepper-growing, and the Bataks of N. Sumatra have long been exclusively devoted to it. The value of the foreign exports from Brunei (Borneo) in 1879 was only 362 dol. In 1801, the S. Bornean district of Banjarmassing was alone capable of producing 1500 tons of the spice. The Java exports of the 1878 crop were:—18,832 *piculs* (of 135½ lb.) to Holland, 2773 to Singapore, 1855 to Italy, 1711 to America, 1000 to the Channel for orders, 244 to Australia, 100 to France, total, 26,515; for the 1879 crop, 6106 *piculs* to Singapore, 4571 to France, 3956 to Holland, 1501 to England, 1253 to America, 644 to Italy, 100 to Australia, total, 18,131. Saigon (French Cochin China) had 2177 acres under pepper in 1879, when 4145 *piculs* (of 133⅓ lb.) were sold at the rate of 3*d.* a lb.; in 1878, the exports were 3500 *piculs*, 5000*l.*; in 1880, there was a great falling off, only 3000 *piculs* being brought into the market. The cultivation is extending in Ceylon. China imports large quantities of both black and white pepper.

Of the former, Hankow took 24,805 *piculs* (of 133⅓ lb.), value 49,920*l.*, in 1879; Kiukiang, 5143; Newchwang, 1435; Ningpo, 1257; Shanghai, 2737.

Whole black pepper is seldom or never adulterated in Europe; but in India, the berries of *Embelia* [*Samara*] *Ribes*, are often mixed with the spice for sale in the bazaars. Ground pepper, on the other hand, is frequently sophisticated with starches and other matters detectable with the microscope, despite the very heavy penalty (100*l.*) which has been in force since 1819. The approximate London market values of black pepper are:—Malabar, 3½–5½*d.* a lb.; Aleppy and Tellicherry, 3½–5½*d.*; Penang, 2⅞–4⅜*d.*; Singapore, 3⅛–4¾*d.*

2. *White Pepper.*—This is produced by the same plant as the black pepper, and is prepared by allowing the berries to ripen, keeping them for 3 days in the house after gathering, washing and bruising them in a basket with the hand till the stalks and pulp are removed, and then drying the white seeds. It is said that the lives of the vines are endangered by allowing the fruit to ripen on them. Sometimes white pepper is prepared from black by removing the dark outer layer of pericarp. The article is most largely prepared in the Straits, but the finest is produced in Tellicherry. China is the great market for it. Singapore exported 48,460 *piculs* (of 135½ lb.) in 1877. In 1879, Hankow imported 250 *piculs*, 885*l.*; Ningpo, 238 *piculs*; Shanghai, 357 *piculs*. The London market value of white pepper is about 4⅜–7*d.* a lb.

3. *Long Pepper.*—This is the fruit-spike of *Piper longum* [*Chavica Roxburghii*] and of *P.* [*C.*] *officinarum*, collected and dried shortly before it reaches maturity. The latter is a native of the Indian Archipelago (Java, Sumatra, Celebes, and Timor). The former is indigenous to Malabar, Ceylon, E. Bengal, Timor, and the Philippines, and is cultivated along the E. and W. coasts of India. In Bengal, the plants are raised from suckers set 5 ft. apart in rich, high, dry soil. The yield from an acre is 3 *maunds* (of 80 lb.) in the 1st year, 12 in the 2nd, 18 in the 3rd; after this, the return diminishes, and the roots are grubbed up, dried, and sold as *pipli-múl*. The pepper is harvested in January, and thoroughly sun-dried. It is brought from Java and Rhio to Singapore and Penang for re-export. Singapore shipped 3366 cwt. in 1871, 447 being to the United Kingdom. Penang despatches 2000–3000 *piculs* (of 135½ lb.) yearly. The London market value is 37–45*s.* a cwt.

4. *Ashantee or W. African Pepper.*—This spice, sometimes called also "African cubebs," is the fruit of *Piper* [*Cubeba*] *Clusii*, widely distributed in Tropical Africa, most abundantly in the Niam-niam country, about 4° to 5° N. lat. and 28° to 29° E. long. It is locally used as a substitute for common black pepper, and could be procured in large quantity.

The essential oils of pepper and other species of *Piper* are described on pp. 1420, 1424, 1425.

Pimento, Allspice, or Jamaica Pepper (Fr., *Piment des Anglais*, *Toute-épice*, *Poivre de la Jamaique*; Ger., *Nelkenpfeffer*, *Nelkenköpfe*, *Neugewürz*).—These names are applied to the immature fruits of *Pimenta officinalis* [*Myrtus*, *Eugenia Pimenta*], an evergreen tree of 30 ft., found in some of the W. Indies. The so-called "walks" of these trees, which afford the whole of the spice found in commerce, occupy the limestone hills on the north side of Jamaica. The range of the tree is curiously limited, nearly all attempts to grow it where it is not found spontaneously fail completely. The only way of forming a new walk is to cut down the other growth found upon land where pimento-trees are growing naturally, thus giving scope for their multiplication. The harvest or "breaking" takes place in July–August, the branches bearing clusters of the fruit being broken off by hand, and the berries subsequently sun-dried, stalked, fanned, and bagged for export. The breaking of the branches serves as a rude kind of pruning. The yield of some trees reaches 150 lb. raw, or 1 cwt. dry. There are curious fluctuations in the returns of the acreages under pimento: thus, 7178 acres in 1871, 1392 in 1874, 2363 in 1875–6, 969 in 1877–8 exclusive of trees growing wild on the pasture-lands. The highest export reached was 6,857,830 lb., 28,574*l.*, in 1870–1; in 1877–8, it was 6,195,109 lb. About ⅔ come to England, and ⅓ goes to the United States. The London market value is about 4½–6*d.* a lb. for middling to good, and 4½–5½*d.* for ordinary.

The volatile oil is described on p. 1416.

Soy.—This useful condiment, said to form the basis of almost all the popular sauces made in Europe, is prepared by the Chinese and Japanese from the fruit of *Glycine Soja* [*Soja hispida*], which holds an important place among oil-yielding plants, and has been described under the article on Vegetable Fatty Oils (p. 1378). The condiment is prepared by boiling the beans with an equal quantity of roughly-ground barley or wheat, and leaving it covered for 24 hours to ferment; salt is then added in quantity equal to the other ingredients, water is poured over, and the whole is stirred at least once daily for two months, when the liquid is poured and squeezed off, filtered, and preserved in wooden vessels, becoming brighter and clearer by long keeping. Its approximate value in the London market is 2*s.* 3*d.*–3*s.* a gal. for Chinese, and 2*s.* 4*d.*–2*s.* 5*d.* for Japanese. It is not specified in the trade returns, but doubtless forms the chief item in the unenumerated spices imported from China.

Vanilla (Fr., *Vanille*; Ger., *Vanille*).—This name is applied to the pods of one or more species of *Vanilla*, the bulk of the commercial article being probably derived from *V. planifolia* [*sativa*, *Myrobroma fragrans*], a native of Mexico, now largely cultivated in many tropical countries, as will be presently described. Other species said to afford the spice are:—*V. sylvestris*, in Mexico, perhaps identical with *V. planifolia*; *V. Pompona*, in Mexico; *V. guianensis*, in British and Dutch Guiana; *V. palmarum*, in Bahia; *V. aromatica*, in Brazil and Peru.

The culture and preparation of vanilla are subject to some variation in different localities. In Mexico, plantations are established in virgin forests or open fields. In the former, all shrubs, climbers, and trees causing an excess of shade are cut down, leaving only young trees to serve as supports for the climbing stems of the vanilla plant. Preference is given to those containing a milky sap, as the plant attaches itself to the bark by means of aërial roots, produced from the nodes, and constituting its true organs of nutrition, for the subterranean roots are quite insignificant, and often suffer gradual decay. Close to each supporting tree, two vanilla cuttings are planted side by side in the following manner; the cutting is embedded in a trench 1½ in. deep and 15–20 in. long, as far as 3 joints or eyes, the 3 leaves having been first stripped off, and then covered with dead leaves, humus, coarse sand, brush-wood, &c., the bed being slightly raised above the surrounding level, to prevent stagnation of water around the plant. The remainder of the cutting, 3–4 ft. long, is tied up to the tree. The trees should be 12–15 ft. apart, to allow room for the rapid growth of the plants. After 1 month, the cuttings will have taken root, and need to be carefully freed from weeds and underwood; in the 3rd year, they bear fruit. When planting a field or open level ground, the land is first ploughed up and sown with maize. Meantime a number of young lactescent trees of the fig tribe spring up all over the field, and, in 12–18 months, are capable of supporting the vanilla-plants, which are then set out as already described. The finest product is obtained in this way.

In Réunion (Bourbon), where artificial fecundation is practised, the plants are not allowed to grow out of reach. When starting a plantation in a forest, the cuttings are set at the feet of the trees, whose trunks are connected transversely by a rude trellis; the trees are never lopped, as vanilla requires humidity, and protection from the direct rays of the sun. In making a plantation in an open field, the first care is to grow supports for the plants. Mangoes and fig-trees are employed for this purpose, though preference is given to *Curcas purgans* [*Jatropha Curcas*], the physic-nut, which strikes readily from cuttings, is of rapid growth, and furnishes abundance of milky juice as sustenance for the vanilla-plant; but Holmes has indicated the possible danger of the acrid matter contained in the juice of this tree (see Nuts, p. 1359; Oils, p. 1410) being absorbed by the vanilla-plant. When the young supporting trees have attained sufficient growth to shade the vanilla, cuttings of the latter are planted as follows:—A trench 8 in. deep is dug between the trees and along the lines in which they grow; the cuttings are set in it, and covered with a little humus, dead leaves, and straw. The rainy season is selected for the operation. When the young shoots begin to grow, it is only necessary to guide them along the trellises, and allow the aërial roots to rejoin the trench between the supporting trees; in 2 years, the plantation is in full bearing.

In India, where the cultivation would doubtless be attended with great success and profit, all trees are good protectors except those which change their bark; the best are the mango (*Mangifera indica*), jack (*Artocarpus integrifolia*), ouatier (*Bombax malabaricum*), and physic-nut (*Curcas purgans* [*Jatropha Curcas*]). The last must not be planted alone, as it sheds its leaves when the vanilla is in full bearing. Perhaps none is better than *Erythrina indica*, already widely utilized as a shade-tree in Eastern agriculture. The best planting-season is March–May. The most suitable tiers are the leaves of the vacoua (*Pandanus utilis*), which will have rotted and fallen off by the time that the plants are able to dispense with them.

Spontaneous fecundation of the plant is comparatively rare, as the labellum or upper lip of the stigmatic orifice completely covers the female organ, and the anther rests on that valve of the stigma. In countries where the plant is left to itself, a length of 12–26 in. of vine only produces one pod, though the number of flowers in that length may be 40. All may be artificially fecundated by slipping away the labellum from beneath the anther, and so bringing that organ into direct contact with the stigma; but only the finest flowers (about ½ doz.) on each bunch should be fecundated, or the plant would die of exhaustion. Fecundation is known to be assured when the flower is persistent and dries at the end of the fruit. The remaining buds should be cut off.

As already observed, the fecundated flower decays at the extremity of the ovary, and, after some days, falls off, leaving the persistent gynostem attached to the fruit, which continues to grow for a month, but must be left on the stem for 6 months longer to allow it to ripen. Each pod should then be cut off separately, as it matures, instead of detaching the entire bunch, as is done in some countries. The only certain indication of maturity is the crackling produced when the pod is pinched between the fingers; the apple-green or greenish-yellow colour is not a sufficiently reliable sign. It is quite as important to avoid gathering the pods too soon as too late. If unripe, the product will lack fragrance, colour, &c.; if over-ripe, the pod will be yellow at the end, and, if not already split, is apt to become so in curing.

The odour of vanilla does not pre-exist in the ripe fruit, but is developed by fermentation. When a pod is allowed to remain on the plant, it splits into two unequal parts, becoming first yellow, then brown, and finally black. While it is drying, it exudes an unctuous liquid of dark-red colour called " balsam of vanilla," and, when quite dry, becomes brittle and devoid of all perfume. The following are the various processes for curing vanilla. In Guiana, the beans are placed in ashes, and there left until they begin to shrivel; they are then wiped, rubbed over with olive-oil, and, their lower end having been tied, are hung in the open air to dry. In Peru, they are dipped into boiling water, tied at the end, and hung in the open air for 20 days to dry; they are then lightly smeared over with castor-oil, and a few days later are tied up in bundles. In Mexico, as soon as gathered, the beans are placed in heaps under a shed, protected from sun and rain, and, in a few days, when they begin to shrivel, are submitted to the " sweating " process. This is carried on in two different ways, according to the state of the weather. If it happens to be warm and fine, the beans are spread out in the early morning on a woollen blanket, and exposed to the direct rays of the sun. At about noon or 1 P.M., the blanket is folded around the beans, and the bundle is left in the sun for the remainder of the day. In the evening, all the vanilla is enclosed in air-tight boxes, so that it may sweat the whole night. The next day, the beans are again exposed to the direct action of the sun. They then acquire a dark coffee-colour, the tint being deeper in proportion to the success of the sweating operation. Should the weather be cloudy, the vanilla is made into bundles, and a number of these are packed together into a small bale, which is first wrapped in a woollen cloth, then in a coating of banana leaves, and the whole, enclosed in a mat, is firmly bound, and sprinkled with water. The bales containing the largest beans are now placed in an oven heated to 60° (140° F.). When the temperature of the oven has fallen to 45° (113° F.), the smaller beans are introduced, and the oven is closed tightly. In 24 hours, the smaller beans are taken out; and 12 hours later the larger ones. During this process, the vanilla has " sweated," and acquired a fine chestnut colour. The delicate operation of drying has now to be commenced. The beans are spread on matting, and exposed to the sun every day for about two months. When the drying is nearly complete, sun-heat is no longer needed, and they are spread out in a dry place until the necessary degree of desiccation is arrived at; they are then tied up in small packets. In the Réunion process, the beans are sorted according to length, to be scalded. The long ones are steeped in water heated to 90° (194° F.) during 10 seconds, the medium size during 15 seconds, and the short ones fully a minute. They are then exposed to the sun between two woollen blankets until they acquire the characteristic chestnut colour. After this exposure, which may last 6–8 days, the beans are spread out under sheds to dry gradually. The sheds in this colony being roofed with zinc, they really constitute drying-stoves, through which a current of hot air continually circulates. This desiccation takes about a month, during which time the only care necessary is to turn the beans frequently, so that they dry evenly. At the moment when it is found that the beans may be twisted easily round the finger without cracking—that is to say, when they have acquired a degree of dryness which can be known only by experience—the operation requiring the most minute and vigilant care commences: this is termed the " smoothing " process. The operator must pass every bean between his fingers, and repeat this frequently, for, on drying, the beans exude from their entire surface a natural fatty oil. It is to this oil, which exudes as the fermentation proceeds, that the lustre and suppleness of the bean is due. When sufficiently dry, they are tied up in bundles of uniform length. In this manner, the three commercial sorts are obtained:—(1) " Fine ": 8–11 in. long, nearly black, unctuous, glossy and clean looking; these soon become covered with frost-like crystals. (2) " Woody ": 6–8 in. long, lighter in colour, more or less spotted with grey, not glossy; these are the pods gathered in an unripe condition; they crystallize very little, if at all. (3) " Vanillons," of which there are two sorts, those obtained from short but ripe fruit, which are excellent, and frost well; and those from abortive and unripe fruit, whose perfume is simply the result of absorption from the fine beans with which they have so long been in contact.

The main centres of vanilla-production are as follows:—Mexico: the slopes of the Cordillera, N.-W. of Vera Cruz, concentrated about Jicaltepec, near Nautla; the *baynillales* on the W. declivity, in Oaxaca State; the States of Tabasco, Chiapas, and Yucatan. E. Mexico exported about 20,000 *kilo.* (of 2·2 lb.) in 1864, viâ Vera Cruz and Tampico, mostly to Bordeaux; the French importations had declined to 6896 *kilo.* in 1871, and 1938 in 1872. Réunion (Bourbon): exported 3 *kilo.* in 1849, and 30,973 *kilo.* in 1877; the crop of 1878–9 was 31,615 *kilo.* The plantations are much injured by periodical cyclones, and by microscopic fungi (chiefly *Bacterium putredinis*), but careful pruning and manuring (phosphoric acid and potash principally, also lime and magnesia) have done much to counteract these evils. Mauritius: this island shipped 7139 lb. in 1872, and 20,481 lb. in 1877; the value was 299,510 *rupees* (of 2*s.*) in 1874, but only 169,966 in 1878. Among other countries, it may be mentioned that the culture is much extending in the Seychelles, and in Ceylon; while the plant is abundant (wild) in Honduras, and grows successfully in Madagascar. Also Panama exported 649*l.* worth to the United States in 1879; and Guatemala, 49 *quintals* to California in the same year. Tahiti exported 1719 lb., 575*l.*, in 1878, and 1426 lb., 570*l.*, in 1879. Very large quantities are grown in Java. The approximate London market values of " salt " pods are 15–40*s.* a lb. for good to fine, and 8*s.*–37*s.* 6*d.* for inferior.

Unenumerated.—Our imports of unenumerated spices in 1880 were from:—China, 7,180,961 lb., 143,476*l.*; British W. Indies, 5,106,803 lb., 104,494*l.*; British E. Indies, 1,781,451 lb., 128,440*l.*; British S. Africa, 1,757,652 lb., 107,504*l.*; Aden, 1,099,733 lb., 68,568*l.*; Native States E. Africa, 723,320 lb., 43,061*l.*; Holland, 414,095 lb., 38,414*l.*; Germany, 213,686 lb., 3542*l.*; other countries, 379,925 lb., 16,806*l.*; total, 18,657,626 lb., 654,305*l.* The total in 1876 was only 7,553,328 lb. The re-exports in 1880 were 12,687,818 lb., 408,623*l.*, chiefly to Germany, the United States, Holland, and Russia. Our imports of unenumerated sauces and condiments in 1880 were from:—China, 893,425 lb., 12,198*l.*; British E. Indies, 314,000 lb., 10,478*l.*; France, 165,040 lb., 4309*l.*; other countries, 112,665 lb., 5169*l.*; total, 1,485,130 lb., 32,154*l.*

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SPONGE (Fr. *Éponge*; Ger., *Schwamm*).

The term "sponge" is commercially applied to the elastic horny skeletons of certain marine animals belonging to the class *Poriferæ*, order *Keratosa*, sub-order *Spongniæ*, family *Spongiadæ*. The commercial grades of sponge in Europe and America coincide very closely. The 3 principal European species are the bath-sponge (*Spongia officinalis*), the horse-sponge (*S. equina*), and the zimocca (*S. agaricina*); in America, these are represented by the glove-sponge (*S. officinalis*, sub-sp. *tubulifera*); the wool-sponge (*S. equina*, sub-sp. *gossypina*), and the yellow and hard-head (both *S. agaricina*, sub-sp. *corlosia*). The most exhaustive account of everything bearing upon the growth and physiology of sponges is contained in Hyatt's very able paper published by the Boston Natural History Society, as quoted in the Bibliography (p. 1821). From it, much of the following information has been derived.

The whole group of *Keratosa* is confined to seas in which the differences between the winter and summer isotherms are not excessive. No American members are found N. of Cape Hatteras and Bermuda; and doubtless a similar limit occurs S. of the equator. On the Pacific shore, S. California and Chili are the extreme points so far known. On the opposite coast of the Atlantic, they are recorded from England to the Cape of Good Hope, and also at the island of Teneriffe. In the Indian Ocean, they are found all along the E. coast of Africa, at the Mauritius, and on the shores of India. They have been described from the S. part of the Sea of Okhotz, on the Asiatic continent, and specimens are not uncommon on the coasts of Australia and New Zealand. In the Pacific, they have been found at the Kingmills Islands and Hawaiian Islands. The extreme outlying form to the north, on both sides of the Atlantic, is the excessively coarse *Dysidea fragilis*, with its fibres loaded with débris. Those from the Cape of Good Hope and S. Australia also belong to the coarser genera. It would seem, therefore, that the finer skeletons of the *Keratosa*, those of the genus *Spongia*, are only to be sought in the intermediate zone, where the waters are of equable and high temperature. And in examining the species of this genus with relation to each other, it becomes equally evident that they are finest and most numerous in archipelagoes, or off coasts which are bordered by large numbers of islands or long reefs, or in sheltered seas. The sponges near Nassau (Bahamas) lie on reefs very much exposed to the action of the waves, often 30 miles from land, and always in currents, sometimes running 3–4 knots an hour. Such currents are usual where groups of islands confine the tide-water within certain definite channels, and they have also the effect of concentrating the floating food in the channels, or wherever tides meet. Both these conditions are essential to successful sponge growth, viz. a continuous renewal of aërated water, and a plentiful supply of food, and are probably partly the cause of the abundance of sponges in such places. Constant reference to physical influence is also noticeable in the method of classification adopted by Von Eckhel.

The marketable qualities of sponge are described as "sorts," and the different sorts are designated by letters, as "sort A." These sorts are most conveniently arranged according to localities, and thus under some sorts all three species are represented; all, however, are from the same place, and all have some local peculiarity which makes them either of superior or inferior quality. The slimy character of the bottom is often given as a reason for inferiority or dark colour. On the American side of the Atlantic, this is also shown by the great difference in point of colour and fineness between the Nassau and Key West sponges. Again, the shallow-water sponges are coarser than the deep-water forms. This is probably due, in part, as in other species, to the quantity of sediment, which is of course less in deep than in shallow water, as, for example, at Key West in the winter time. No fine qualities of any sponges are found within the limits of the milky water, but all the finer qualities of the marketable kinds in the deepest water in which the species occur, except, perhaps, in the case of the reef sponge. Glove, reef, and hard-head are fished in shallow waters (greatest depth 2 fathoms), and the other and generally finer marketable varieties at 2–5 fathoms. This fact also explains in a measure, but not wholly, the greater coarseness of American sponges as compared with the European; for though it may be assumed from the examination of the skeletons that Mediterranean sponges are much less exposed to turbid waters, and though it may be shown by the microscope that the primary fibres contain less débris, this does not wholly explain their greater fineness and elasticity. This may be attributed either wholly or partly to climatic conditions. Both the bathymetrical and geographical distributions of the *Spongiæ* seem to be limited by the minimum temperature of 13° (55° F.). The N. shore of the Ægean Sea and the E. shore of the Adriatic are populous with sponges, and yet the former throughout its whole extent, and the latter from Ragusa to Istria, have nearly the same average winter temperature as, and possess a colder climate in winter than, the coast of S. Italy or Spain, where no *Spongiæ* exist. The sponges correspond in quality to this climatic change. The sort found at the head of the Ægean is said to be *S. officinalis* alone, and to have a heavy, hard, close, very hairy skeleton, often containing slime. The same species exists also alone at corresponding localities along the shore of the Adriatic, and at the extreme locality, the island of Istria, upon the limit of its distribution, it is said to be very rare, the form to be ugly, the skeleton hard, the colour dark. Farther south, along the Dalmatian coast, it becomes abundant, finer in texture and of a lighter colour, but it is still inferior to the more southern or Levantine variety. In considering such classes of facts, it must also be borne in mind that the habitat of a certain sort or variety may largely determine the quality of the skeleton, even where the temperature may be very favourable. Thus, to the south of Quarnero, among the islands, a much better quality of *S. officinalis* occurs than in the milder sea about the Ionian Islands, which is probably attributable to the slimy character of the bottom. It would seem, from the absence of sponges where they might be expected to occur, that when the limits of temperature are neared, the lack of small islands, or very slight local peculiarities, may suffice to account for commercial sorts (to which our knowledge is confined) being wanting.

The finest sponges in the Mediterranean, those of the Levant and off the Syrian and Tripoli coasts, are found between the average aërial temperatures of 17° and 21° (63°–70° F.), and the isochrymals of 10°–14° (50°–57° F.), and probably at no time of the year are these, which occur in the deeper water at a distance from the coast, exposed to a lower temperature than 15½° (60° F.). In America, the whole region favourable to the production of the commercial qualities lies between St. Marks, on the coast of Florida, with an isotherm for January of 17½° (63½° F.), and the equatorial isotherm for January of 27° (80° F.); south of this equatorial isotherm, however, the limits have not been ascertained, the data, both as regards the sponges and the temperatures, being deficient. The finer sorts are only found along the W. coast of Florida, among the Keys, and in the insular waters of the Bahama and Caribbean Islands. Their absence from a large part of the shore of the Gulf of Mexico may be attributed to the sandy or soft character of the coast, the silt of the Mississippi, and the absence of outlying islands; the open and sandy or clayey character of the Atlantic coast northward to New York explains their non-occurrence there.

The sponges of the Red Sea are inferior to and rarer than those of the Mediterranean; they most resemble the zimocca kind, the skeleton being brittle, entirely red, and very dark at the base; and the two sorts are sold mixed. It therefore seems that the high temperature of the Red Sea, in presence of perfectly clear water, is not so detrimental as where the waters are more loaded with sediment, as in the shallows of the Florida coast, or the specimens could not be sold commercially in the company of even the inferior Mediterranean qualities. The few true Australian *Spongiæ* are coarse, and have an excessively dark rough skeleton. The Sydney sponges, found under the marine isochrymal of 62° F., on an open and unfavourable coast, are presumably beach specimens, drifted from the coast of Queensland, which, inside the great boundary reef, is probably exceedingly favourable to the growth of the true *Spongiæ*. From all the ascertained facts, Hyatt deduces five rules as governing the quality of commercial sponges:—(1) The inferiority of the skeleton, which is common at Key West, with the same isochrymal as the Red Sea, is not found in the same degree in the sponges growing in the clearer waters of the latter; (2) the coarsest qualities of all the Mediterranean sponges, the "Gerbis" and others, grow in localities along the coast, where they are most subject to the action of suspended matter in the water; (3) but all of these are, on account of the clearness and medium temperature of the Mediterranean waters, as compared with those of other seas, of much finer quality; (4) the coarser kinds of the same quality or variety grow nearest the shore, and the finer kinds in deeper water, and, according to Nassau (Bahamas) spongers, are more apt to occur upon marly ground, where the sediment is finer than upon other kinds of bottom; (5) the inverse ratio between the quantity, and even the prevalence, of different kinds of sediment, such as sand grains or spicules, and the resiliency and flexibility of the fibres of the sponge, may be demonstrated with the microscope in any series of specimens.

The openness or apertion which usually accompanies and appears to correlate with the coarseness of fibre cannot be accounted for in this complicated way, but must be considered as an element of inferiority always accompanying a skeleton having loose microscopical texture or mesh, and harsh, inelastic, easily torn fibres; but it is also, though rarely, found in specimens of very fine quality, especially at an early age. It is a common characteristic of all inferior qualities of Mediterranean, and of all Caribbean commercial sponges without exception; the latter, whether with very fine or very coarse and inelastic fibres, are always permeated in the interior, and have the surface also cut up, by larger and more numerous canals than the corresponding Mediterranean species. The Australian *Spongia spp.*, though coarser in fibre than the Caribbean, are equally open, and usually much harder when dry. The evidence afforded by unmarketable varieties found in very hot climates, and all of which have very open, coarse, and brittle skeletons, confirms the opinion that this characteristic of apertion may with good reason be attributed perhaps exclusively to the influence of unfavourable temperature, which may be either a degree of cold indicated by an isotherm of about 50° F. for the coldest months, or the equally injurious heat shown by an average for the same months of 65°–80° F.

With regard to colour, a darkening of the fibres about the base, and frequently of the whole sponge, may occur with any of the inferior qualities in any cold climate or unfavourable situation, as at Istria, and varies with the age and size of the specimen. These influences, however, never produce so marked an effect as in a hotter climate, nor does the deterioration of the fibre and of the density of the skeleton go so far; nevertheless, the Nassau sponges, which are lighter coloured than the Gerbis, and the foregoing remarks upon the influence of suspended matter near the shore, point to the fact that heat does not entirely control the colour, though it may largely influence it. Another point in this connection is that the deepest colour is always in the interior, and the lightest coloured parts are external, in the position most exposed to the action of light; and this, though not necessarily, is probably the hottest part of the organism during the heated term of the year in the shallower waters, where the darkest-coloured forms are mostly found. It has been suggested that this coloration was due to iron in the sediment or sea-bottom; but this could hardly be the case in the vicinity of coral reefs, and the dark internal coloration appears to result from or correlate with the deterioration of the skeleton as an internal change in structure, varying with the species, the age, and the health of the specimen, and probably with the chemical composition of the fibres themselves.

The distribution of the species is quite remarkable. Only one species (*Spongia officinalis* [*adriatica*]) is found on the E. shore of the Adriatic and coast of Greece, from Trieste to the Bay of Nauplia. From Nauplia and the island of Candia to Eritra, on the coast of Asia Minor, two occur, *S. officinalis* and *S. agaricana* [*Zimocca*]. From Eritra, opposite the island of Chios, to Tripoli, all three, *S. officinalis*, *S. agaricana*, and *S. equina*, are fished, except at the island of Cyprus, where the zimocca sponge does not live. From Tripoli to Tunis, two only occur, *S. officinalis* and *S. equina*; and from thence to Ceuta, at the Straits of Gibraltar, a very peculiar dark-coloured and coarse variety of *S. equina* is obtained, called the Gerbis (Gerba) sponge. The dealers have thus to do with a vast variety of forms. They can, however, pick out the three species and their varieties without hesitation, being led mainly by the general aspect of the surface. This has a distinct appearance in every species, and, though much altered by the greater or less development of superficial tufts, is much more constant than any other character. This is due to the fact that the surface takes its aspect largely from the number, distribution, and size of the pores, cloacal orifices, superficial canals, and primary fibres. These characteristics, of course, are directly correlated with all that is important in the internal anatomy of the animal, and should therefore be more constant than the length, form, or composition of the tufts of fibres, or the shape of the whole, which are capable of great modification, according to the locality in which the specimen may be found. The forms of *S. officinalis* may vary from cup-shape to fistular, and to irregular or lump-like. The latter are usually coarser and looser in texture, the superficial tufts are longer and more numerous, and they approximate more closely to the coarser varieties of sub-sp. *tubulifera* of the Caribbean Sea, in the external aspect of the surface and the apertion of the interior, than the finer varieties. The texture of the poorest variety of the Mediterranean sponges is, however, always better for domestic purposes than the best of the corresponding American varieties, being firmer and more elastic; and it is also to be remarked that the latter never have the cup-shape, which is so common in the sub-sp. *mediterranea*, and that the fistular form takes its place. The forms of *S. agaricina*, sub-sp. *Zimocca*, vary from saucer-shape to irregular lump-like growth. As in *S. officinalis*, it may be shown that these aberrant forms are quite similar to the aberrant or formless varieties of the sub-sp. *punctata* of Florida, as regards the aspect of the surface; but these also are nevertheless much finer than the finest varieties of the latter. Here, again, the platter- or saucer-shape, which is a modification of the cup-shape, is absent. *S. equina* exhibits similar degrees of variation in the texture of the surface and the form. There are no proper cup-shaped specimens among the American varieties of sub-sp. *gossypina*, but, in place of these, the fistular form. These occur generally associated in clumps, more or less densely filled up into heads, and solid; but sometimes the tubes are almost isolated. The younger specimens of this species have a very loose and open texture, due to the approximation and large size of the openings, and, to a less degree, this is also to be remarked in the Gerbis sponge. The former approximate in aspect to the coarser qualities of the American species; so also does the latter, which has very nearly the same colour and aspect as the dark-coloured Key West specimens, but it is not so coarse and dark. It seems, then, that there are three sub-species of commercial value in the Mediterranean, which find their way into the New York and European markets. The coarsest varieties of the European sponges are finer, firmer, and more elastic than the finest of the corresponding American sub-species. This is directly traceable to the larger amount of foreign matter included in the primary threads, and the looser mesh of the tissue; the fibres are also comparatively coarser, and the large cloacal channels more numerous throughout the mass. The shape does not necessarily correlate with a finer or coarser skeleton, but probably with a more or less extended base of attachment, and with local peculiarities, such as currents, the kind of bottom, &c., which have not been investigated in this connection.

Sponges always grow on hard surfaces—rock, coral reef, bricks, the barren stems of sea plants, &c. They are sought for in shallow water by the aid of a water-glass, which is a tube of thin boards or iron pipe several feet long, with a pane of glass at one end (often merely a bucket with a glass bottom), which, when submerged, prevents the sight of the fisherman being disturbed by the glare of the reflecting surface and by its incessant motion. The latter obstacle alone is sometimes overcome by simply pouring oil on the surface of the water. When found, they are dislodged either by divers, or by so-called "harpoons." The divers descend either naked or in special dresses. When naked, they are carried down by a block of stone weighing some 25 lb., held at arm's length in front. The usual depth is 15–20 fathoms; but some divers successfully reach 40 fathoms, after inflating the chest for about 10 minutes. The ordinary duration of a dive is 1–2 minutes, and 3½ is the maximum. The use of the harpoon, a kind of fork on a thin pole 3–6 fathoms long, dispenses with diving; it is used for the coarser Mediterranean and most of the Caribbean sponges, which grow in shallow water, and are not worth the risk and trouble of diving. A third plan is by dredging with a drag-net, which tears up the sponges and collects them in a bag behind.

About 12 hours' exposure to the air suffices to kill the sponge. Subsequent operations are designed to free the skeleton from the animal's remains. In the Mediterranean, as soon as the first sign of putrefaction makes its appearance, the sponges are tied to strings and kneaded in sea-water with sticks or with the feet, till the "milk" or sarcode and the skin are quite removed, the latter being sometimes scraped off with a knife. This is performed much more rapidly in warm than in cold weather. Sponges should always be washed if possible within 24 hours of their capture, never being so good if left till the next day. When perfectly clean, they are dried by exposure to the air, and then packed in bales. If packed before fully dry, they heat and become spoiled, assuming an orange-yellow colour; partial remedies for this have been found in the weak acids, as citric, and in alkaline solutions. Sponges may be bleached by sulphurous acid, or by Blondeau's recipe, which is as follows:—They are first washed in warm water, and then in a solution containing 0·5 per cent. of hydrochloric acid, to remove the carbonate of lime; the actual bleaching is effected by a 24 hours' immersion in a bath containing 5 pints hydrochloric acid, and 6 pints hyposulphite of soda, in 100 pints water. This is said to be a more effectual and rapid process. But all bleaching must be at the expense of the durability of the sponge. In America and the Bahamas, want of care marks the conduct of the operations, the "killed" sponges being cast into pens formed by stakes driven into shallow water, called "crawls," and left to decompose as they may. They are finally squeezed, washed, dried, and sun-bleached. In the S. Pacific, much the same method prevails, the sponges being suspended from a light framework, so that they are washed by the tide when up, and exposed to wind and sun while the tide is out.

The chief localities of sponge-fishing cited by Eckhel are as follows:—The bays of Patras, Corinth, Koron, Marathonisi, Nauplia, Kranidi, Budrum; the islands of Cerigo, Hydra, Spezia, Ægina, Poros, Salamis, Astrupala, Samos, Pathmos, Leros, Nisseros, Kalymnos, Symi, Chalki, Rhodes, Candia, Cyprus; on the W. coast of Asia Minor, the localities of Chesme, Eritra, Samos, Mendelia, Dschovata, Makry; on the Syrian coast, Latakia, Tarabulus, Ruad Island, Batrun, Dschebel, Beyrout, Caiffa, Jaffa; the Straits of the Dardanelles, and the Sea of Marmora. The "harpoon" fishing is carried on chiefly at Nauplia, Kranidi, Hydra, Spezia, Ægina, Poros, and Salamis, while the divers affect Symi, Kalymnos, Chalki, and Castell-rosso. Eckhel further classifies the 3 species into the following commercial sorts:—(A) Dalmatian: (1) Istria, (2) Dalmatia; (B) Patras or Gulf; (C) Greek: (1) Koron, Marathonisi, and Cerigo, (2) Nauplia, Kranidi, Hydra, Spezia, Ægina, Poros, Salamis; (D) Turkish: Volo, Trikeri, Argalesti; (E) Bugaso: Dardanelles and Marmora; (F) Astrupalia; (G) Island: (1) Samos, Pathmos, (2) Leros, Nisseros, (3) Budrum, (4) Kalymnos, (5) Symi, (6) Chalki, (7) Rhodes, (8) Castell-rosso; (H) Kankava: Chesme, Eritra, Samos, Mendelia, Dschovata, Makry; (I) Candia; (K) Karamania; (L) Cyprian; (M) Syrian: (1) Latakia, Ruad, Tripoli, (2) Batrun, Dschebel, Beyrout, Caiffa, Jaffa; (N) Mandrucha or Barbarian: (1) [Katomeri] Arabian Gulf, Gatta Gulf, Mellach, (2) [Panomeri] from Mella to Derna, (3) Bomba, Tobruk, Ras-et-Tin, Tunia; (O) Bengazi; (P) Gerby or Sfax: Tunis; (Q) Red Sea; (R) Bahamas.

The exports of sponge from Syra in 1879 were:—4023*l.* worth to Great Britain (18,689*l.* in 1877), 7242*l.* to France, 1827*l.* to Austria. The average value of the Greek sponge is 2*s.* a lb. Tripoli yearly produces 25,000–35,000; the exports in 1878 were 15,000*l.* worth to England and France. The United States fisheries produced 12,995 lb., value 5044 dol. (of 4*s.* 2*d.*) in 1877; the returns for 1877 and 1878 are incomplete. The exports of sponge from the Bahamas have fluctuated in value as follows:—1869, 24,917*l.*; 1870, 14,104*l.*; 1873, 32,938*l.*; 1877, 17,337*l.*; 1879, 33,265*l.* The qualities and values of the Bahaman sponge exported in 1878 and 1879 were:—

	1878.		1879.	
	lb.	£	lb.	£
Boat	19,165	686	19,817	737
Glove	17,292	521	10,866	369
Grass	174,228	2,003	132,491	2,987
Hardhead..	37,530	1,560	36,538	1,704
Mixed	4,320	149	9,082	271
Reef	33,840	2,934	42,334	3,682
Refuse	14,322	210	1,972	24
Velvet	62,708	5,277	101,184	8,843
Wool	86,393	10,406	102,862	13,258
Yellow	35,787	990	41,301	1,410
	485,585	24,736	504,447	33,285

Our imports of sponge from the Mediterranean were 189,828 lb. in 1851; 411,111 lb., 270,410*l.*, in 1860; 453,819 lb., 113,384*l.* in 1870. Our total imports were 1,221,673 lb., 156,965*l.*, in 1869; 837,159 lb., 160,162*l.* in 1870. There are no records since. The approximate London market values of sponge are:—Turkey: fine picked, 16–22*s.* a lb.; fair to good, 7–10*s.*; ordinary, 8*d.*–3*s.* 6*d.*; Bahama, 5–10*d.* The ordinary applications of sponge are sufficiently familiar. Attempts have been made to utilize the very inferior qualities, which are unfit for use as sponge, for the manufacture of a kind of felt. The process consists in softening with glycerine, cutting small, carding, and felting. The manufacture does not appear to have flourished long.

It would be an omission to conclude this article without an allusion to the efforts which have lately been made to artificially improve sponge-culture. The object aimed at was the multiplication of sponges by cuttings; but inasmuch as the cuttings were found to produce no greater return than would have been given in the same time by the single specimen uncut, the only advantage derivable from the process would be the possibility of populating suitable unoccupied ground with cuttings of commercially valuable kinds. Details may be consulted in Dr. Marenzeller's paper quoted in the Bibliography (translated in the Society of Arts Journal, Vol. xxix., No. 1488), and in the Pharmaceutical Journal, Vol. xi. [xl.], No. 547, pp. 491–3.

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STARCH (Fr., *Fécule*, *Amidon*; Ger., *Stärke*).

The term "starch" is applied to the fecula or amylaceous matter contained in the fruits, roots, or cellular tissue of by far the greater number of plants, and extracted from a few on a commercial scale. It occurs in grains of various sizes, having when pure a slightly yellowish colour, and whose form and structure are characteristic for each kind; the bluish tint of laundry-starch is due to the addition of a mixture of smalt and alum in water: such starch is considered unfit for dietetic or medicinal use. The sp. gr. varies with the kind of starch, and with its dryness; the amount of water reaches 30 per cent. in some instances, and at times descends to 7 when air-dry. The formula is variously given as $(C_6H_{10}O_5)^2 + 3OH_2$, $C_{18}H_{30}O_{15}$, and $C_{36}H_{62}O_{31} + 12OH_2$. Some starches are prepared for use as alimentary substances, while others are only converted into an article for industrial application. The best qualities of starch serve for sizing paper, especially fancy papers (see pp. 1489–90). The finest starch is used for the manufacture of white glucose syrups (see Sugar—Starch-sugar), for finishing textiles (see pp. 770–6, 1185), for making white dextrine (see pp. 1645–7), as well as for preparing farinaceous food and fine pastry. Inferior sorts are used for the same purposes when the quality is not of such importance, as for instance, for weavers' dressing, as a means of thickening mordants (see pp. 1293–1305), and colouring substances for cloth printing (see pp. 835–54). By fermentation, it produces glucose and then alcohol (see pp. 192–214). Another important application is the "dusting" of the forms in metal foundries, in lieu of charcoal dust. Its use for stiffening ("starching") linen and washed clothes is well known.

The principal kinds of starch will now be separately described. They can be distinguished under the microscope by the shape of the granules: in rice, they are small and angular; in maize, angular but larger; in wheat, lens-shaped; in potato, arrowroot, and *tous-les-mois*, more or less ovate; in tapioca, muller-shaped. They vary in size from $\frac{1}{250}$ to $\frac{1}{10000}$ in.

Arrowroot.—The name "arrowroot" embraces the amylaceous matter of several kinds of plant very widely disseminated in the tropics. The most important of these is *Maranta arundinacea*, a native of the W. Indies and Tropical America, from Mexico to Brazil, and occurring under the form known as *M. indica*, which has narrower, sharper, and always smooth leaves, in Bengal, Java and the Philippines. It is also cultivated in Mauritius and Natal, and on the W. coast of Africa.

In Bermuda, arrowroot is planted in May and ripens in March–April; it is manufactured in April–May, during the cold winds. The process is simple. The washed rhizomes are reduced to a pulp, which is strained through sieves of progressive fineness, allowed to settle, collected, passed through the finest sieve into clean water, settled, and the layer of brown colour removed from the surface. This brown starch is the more astringent of the two, and is locally preferred. After a final passing through the finest sieve, and settling, it is placed on cloths to harden, broken up fine on trays, and dried in the sun and wind. About 100 lb. good arrowroot may be got from 4 barrels of the peeled and cleaned rhizomes, about 24 hours being the duration of the water process. In Jamaica, rude machinery is used for the pulping operation. The one great precaution necessary is the absolute avoidance of contamination with dust, rust, insects, or anything capable of communicating odour or colour; hence a good supply of pure water (especially free from iron) is pre-eminently requisite. The refuse of the plant forms excellent pig-feeding material. The production and exports of arrowroot from the W. Indian Islands are exhibited in the following figures. Bermuda shipped 10,334*l.* worth in 1851, which gradually decreased till the quantity in 1870 was only 25 cwt. The quality of Bermuda arrowroot has never been surpassed, mainly on account of the care exercised in its preparation. Jamaica has about 50–60 acres under arrowroot; the exports were 70,204 lb. in 1866, 13,193 in 1871–2, 1636 in 1873–4, 21,983 in 1874–5, 3514 in 1876–7. St. Vincent shipped 10,379 bar. in 1870, 17,669 in 1877, and 14,916 in 1879. Barbados exported 114*l.* worth in 1877, and 24*l.* in 1878. Grenada shipped 20 lb. in 1878. In the adjacent colony of British Guiana, the plant is readily cultivated, but the product is very inferior through carelessness in the preparation. Dutch Guiana (Surinam) exported 621½ *kilo.* (of 2·2 lb.) in 1877, and 89 in 1878.

In Natal, arrowroot-culture is carried on chiefly in the counties of Durban, Victoria, and Tugela; also in Cape Colony. The land, preferably old, is well ploughed and broken up at the commencement of the rains; sets taken from old stools are planted thickly in a simple plough-furrow, and covered with earth turned out of a parallel furrow. The plant grown is the same as in the W. Indies, and the mode of preparation is practically identical. The area occupied by arrowroot in Natal was 226 acres in 1864, and 386 in 1870. The yield varies much: 61 acres in Tugela gave 1220 cwt.; 66 in Victoria, 639; 98 in Durban, 488. The exports were 6366 cwt. in 1859, 1206 in 1874.

The same plant is considerably cultivated in India, but much of the E. Indian arrowroot is afforded by another genus. In the S.-W. districts, notably Travancore, Cochin, and Canara, *Curcuma angustifolia*, *C. leucorrhiza*, and perhaps some other species, are extensively grown, and their starch, known as *tikor* or *tikhar*, is prepared by rude processes.

Maranta nobilis seems to be the kind chiefly cultivated in New South Wales. Queensland grows not only *M. arundinacea* and *C. edulis*, but also 3 species of *Manihot* (see Tapioca, p. 1828). The area occupied by arrowroots of all kinds in Australia in 1879 was:—Queensland, 132 acres; New South Wales, 27 acres (produced 47,484 lb.); Victoria, 4 acres (produced 67 cwt.). Queensland in 1869 exported 26,368 lb., value 548*l.*

Several species of *Canna* are cultivated for their starch, that produced in St. Kitts being known as *tous-les-mois* (a corruption of *toulema*, *tolomane* or *touloula*). The species have not been accurately determined, but it would appear that *C. edulis* [*indica*] is the one mainly or exclusively raised in the W. Indies, while others mentioned are *C. Achiras*, a native of Peru, *C. flaccida*, of Carolina, and *C. glauca* and *C. coccinea*. The island of St. Kitts (W. Indies) exported 51,873 lb. of this arrowroot in 1876. Some is also produced in Australia (from *C. edulis*), the plants being set in ordinary ploughed land, and harvested in April. *Tous-les-mois*, when boiled with 20 times its weight of water, yields a more tenacious jelly than the *Maranta*-starch.

Tahiti or South Sea arrowroot is obtained from the tuberous root of the *pia* of Tahiti (*Tacca pinnatifida*), a plant affording over 30 per cent. of starch, also said to occur in China, Cochin China, the Moluccas, Zanzibar, &c. The area occupied by the culture of this plant in Fiji in 1879 was 2215 acres. Other species met with in India, Madagascar, Guinea, and Guiana, might be utilized in a like manner. The starch of *T. involucrata* is extracted on the W. coast of Africa.

Arrowroot is also locally obtained and used from various species of *Zamia* in Florida, under the name of *boonti*, from *Z. integrifolia* and *Z.* [*Encephalartos*] *spiralis*; in Queensland and W. Australia, from another species, which contains 30 per cent. of starch resembling arrowroot in feel and taste. Portland arrowroot, not now to be met with in commerce, was formerly prepared from the roots of *Arum maculatum*, in the island of Portland. Small quantities of starch are also obtained from *A. italicum* in Italy. The starch of the root of *Alstrœmeria Ligtu* and other species is used as arrowroot in Chili.

Arrowroot is a brilliantly white, insipid, odourless powder, crackling under pressure in the hand, of sp. gr. 1·565 after drying at 100° (212° F.). The various kinds may be distinguished by the microscope by the differences in the size and form of the granules. The chief commercial kinds and their values are:—Bermuda, 1*s.*–1*s.* 6*d.* a lb.; St. Vincent, 2½–7½*d.*; E. India, 1¾–2½*d.*; Natal, 3½–7*d.* The imports of arrowroot into the United Kingdom in 1870 were 21,770 cwt., value 33,063*l.*; the value in 1875 was 56,143*l.*; there are no returns since. The domestic consumption of arrowroot is sufficiently familiar.

Buckwheat-starch.—A few English firms prepare starch from buckwheat (*Polygonum fagopyrum*). It is a fine powder of nearly pure-white colour. (See Wheat-starch, pp. 1828–9.)

Greenheart-starch.—The starch obtained from the seeds of the greenheart or *bibiri* tree of British Guiana (*Nectandra Rodiœi* [*leucantha*], to the extent of 50 per cent. and upwards, is locally used as food in times of scarcity. It has a bitter flavour and pale-brown colour, and is said to possess febrifuge and tonic properties.

Horse-chestnut starch.—The fruit of the horse-chestnut (see Nuts—Chestnut, pp. 1352–3) contains 16–36 per cent. of starch, which is readily extracted by the methods that are adopted for corn-starch. The preparation of the article is largely carried on in S. France, 100 lb. dry starch being obtained on an industrial scale from 240–250 lb. of the "nuts." The bitterness is removed by treating with water containing carbonate of soda.

Maize-starch.—The grain of the maize or Indian corn plant (*Zea Mays*) contains a large proportion of starch, the average quantity being about 53½ per cent. in flat yellow American maize, and 54¾ in the flat white and round yellow varieties. In its occurrence and association, the starch of the maize closely resembles that of wheat; it differs in that the accompanying gluten forms a less tough mass, and may be separated without having recourse to fermentation, thus affording a bye-product of greater value for cattle-feeding purposes. The grain is cleaned, soaked in water for 24–30 hours, crushed in a roller-mill or ground to paste between millstones, and washed in cylinder-sieves as described for potato-starch (see Fig. 1287, p. 1825). The starch-milk thus separated is poured upon inclined tables where the starch granules are deposited, while the nitrogenous matters pass on to capacious tanks, and gradually subside, to be subsequently collected and mixed with the hulls for cattle-food. The starch which settles in the inclined tables forms a good paste for finishing textiles, without further treatment. The quality may be improved by the application of alkaline solutions, which dissolve the remaining gluten.

There are several modified methods of manufacturing maize-starch. Watts steeps the maize at a temperature of 25°–60° (77°–140° F.) until slight fermentation has set in. Leconte soaks the grain in a caustic soda solution, washes it in a wire sieve, and crushes it between millstones on which plays a jet of water. The starch-milk is filtered on to the inclined tables.

The finer qualities of maize-starch are largely used as a substitute for arrowroot and for making biscuits, while the lower grades serve for laundry purposes. The most extensive factories where it is produced are Brown and Polson's in Scotland, Erkenbrecher's in Cincinnati, and the Glen Cove Co. in New York; it is also made in Brazil, New South Wales, France, and Hungary on a considerable scale.

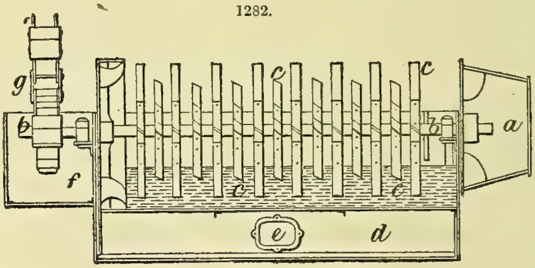
Plantain-starch.—This starch, sometimes called Guiana arrowroot or plantain-meal, is extracted from the unripe fruit-pulp of *Musa paradisaica*, by slicing, sun-drying, powdering, sifting, and washing with water. The article is mostly exported as meal to Europe, and the starch is manufactured after arrival. The flour is said to contain 66 per cent. of starch.

Potato-starch (Fr., *Fécule de Pomme-de-terre*; Ger., *Kartoffelstärke*).—The potato (*Solanum tuberosum* [*esculentum*]) contains starch to the extent of 15–25 per cent.; the amount varies according to the soil, climate, manuring, and storage—freezing and sprouting being alike detrimental. About 66–75 per cent. of the contents are obtained by the manufacturer.

There are chiefly two methods of manufacturing potato-starch. According to the older and commoner plan, the potatoes are first cleaned and then grated. The cleaning embraces the washing away of the attached dirt, and the elimination of stones and other foreign bodies. Many machines have been devised for the purpose, one of the best being Venuleth's, shown in Fig. 1282. It consists essentially of an iron receptacle *a* for the dirty potatoes, a shaft *b* carrying wooden beaters *c*, which revolve in a trough of water, provided with an iron grating which allows the dirty water to escape into a lower trough *d*, whence it can be withdrawn at the door *e*. The washed potatoes pass into the box *f*, ready to be conveyed by the elevators *g*, into the grating-machine, which usually stands on the floor above.

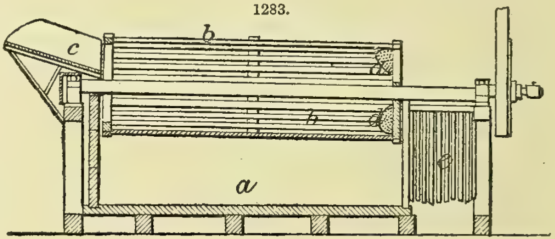
Another form of washing apparatus is shown in Fig. 1283, and is known as Champonnois'. It consists of a wooden tank *a* filled with water, in which revolves a cylinder *b*, formed of open woodwork. The potatoes are fed by the hopper *c*, washed by the rotation of the cylinder, and thrown by the lips *d* upon the external inclined plane *e*, also formed of laths.

1282.



The grating or grinding of the washed potatoes ruptures their cells, and liberates the starch to a greater or less degree. Of the numerous graters in use, one of the best is Champonnois', shown in Fig. 1284. The potatoes are introduced by the hopper *a*, and are forced by the rapid rotation of the fliers *b* (800–1000 rev. a minute) against the short saw-like teeth of the raspers *c*. Water is at the same time injected at *d*; *e f* are the fast and loose pulleys, and a fly-wheel is fixed on the end of the shaft *g*. The motion of the machine is reversed every 6 hours to equalize the wear, still the raspers require sharpening after 48 hours' use. The whole interior needs frequent washing out with clean cold water, and the raspings should be removed at very short intervals.

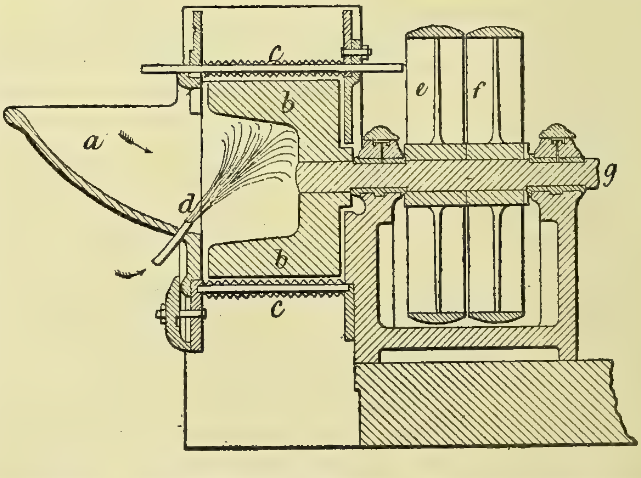
1283.



The grated paste next requires treatment to separate the starch-granules from the cellular and fibrous matters. This is effected by sifting-machines of various kinds with the aid of water. One of the simplest forms is shown in Fig. 1285; the brushes *b* rotate over the surface of the wire or hair sieve, while water is supplied by the pipes *a*; motion is given by the pulley *c* and bevel-wheels *d*.

Siemens' bolting-sieve is shown in Fig. 1286. The grating-cylinder *c* is secured to a simple wooden frame *e*; the paste falls from the cylinder upon the bolting-sieve *h*, supported from the frame by bars *f*. The grating-cylinder is driven by a pulley, and transmits motion to the pulley *d*, which connects with the sieve by the bar *g*. The sifted paste is conducted by *k* to the receptacle *l*. Water is admitted to the cylinder at *a*, and to the sieve at *i*, while *b* is the feed-hopper. The liberated starch is conducted into settling-tanks.

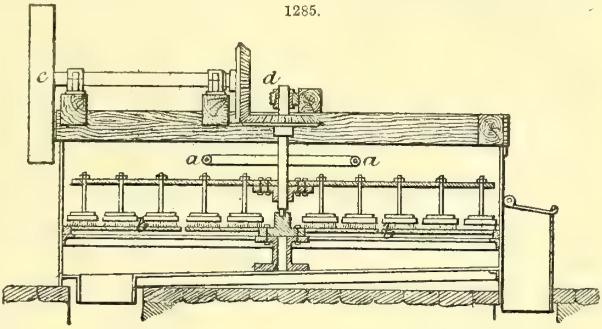
1284.



Huck's sieve, Fig. 1287, is composed of three sieves *a* placed end to end, but separated by cylindrical chambers *b* of greater diameter. The mesh of the sieves is of increasing degrees of fineness. The sieves rotate in the opposite direction to the brushes which impinge upon their surface, and to the iron arms in the intermediate cylinders. The paste from the rasper falls into the first sieve, where it is strongly agitated by the brushes, while water is admitted by jets throughout the whole length of the sieve. In the intermediate cylinders *b*, the paste is stirred up with the water by the iron arms.

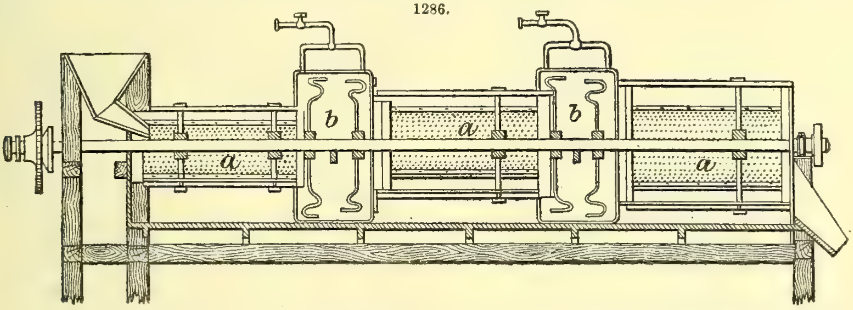
The sifted and washed starch is allowed to deposit itself in large tanks, and when this has sufficiently taken place, the water is drained off, and the deposit is again washed with water. The milky liquid is drawn off in a thin stream and passed over an inclined plane, on which the starch deposits itself at varying distances from the head of the plane, according to its quality. It still requires a washing in clean water. Sometimes centrifugal machines are employed. Fesca's is shown in plan in Fig. 1288; the drum *a*, made of ¼-in. sheet-iron, is driven by the belt *b*. Other centrifugal machines will be found described under Bleaching (pp. 495–6) and Sugar.

1285.



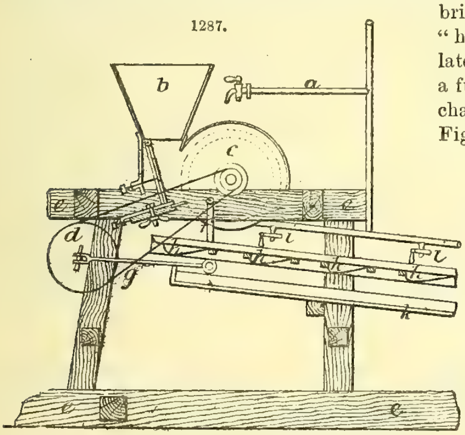
Potato-starch is largely bleached by the application of sulphuric acid; this being absolutely requisite when the potatoes are at all decayed. After the use of the sulphuric acid, any possible remaining traces must be neutralized by ammonia or milk of lime, fixed caustic alkalies being inadmissible. Chlorine is also much used for bleaching starch, usually as a solution of calcium chloride in water soured by the addition of sulphuric acid; this and some other salts cause the grains to swell, and render them soluble in cold water. Sal ammoniac is another favourite agent.

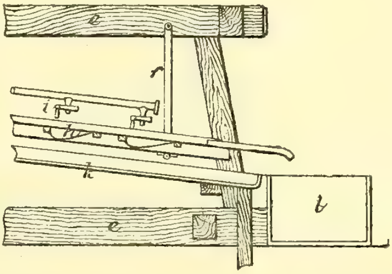
1286.



The manufactured starch finally requires drying. This is primarily effected by spreading it on bricks or gypsum slabs, and then by laying it on "hurdles" in a room which is thoroughly ventilated, and through which is passed air heated by a furnace beneath. An improved form of drying-chamber by Lacambre and Persac is shown in Fig. 1289. The starch is introduced at *a* upon a series of linen trays *b*, all of which revolve at a uniform speed, so that the starch is gradually transmitted from one to the other till it reaches the receptacle *c*, having been completely dried in its passage by encountering the hot air derived from the furnace *d*.

1287.

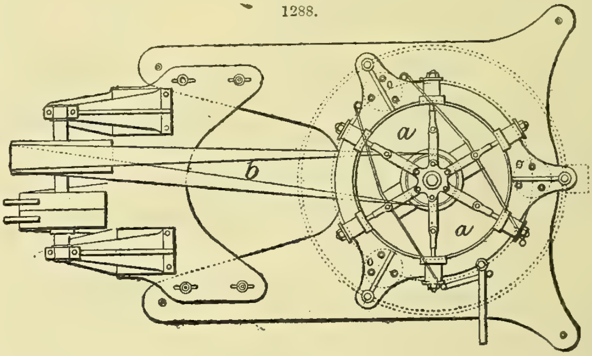




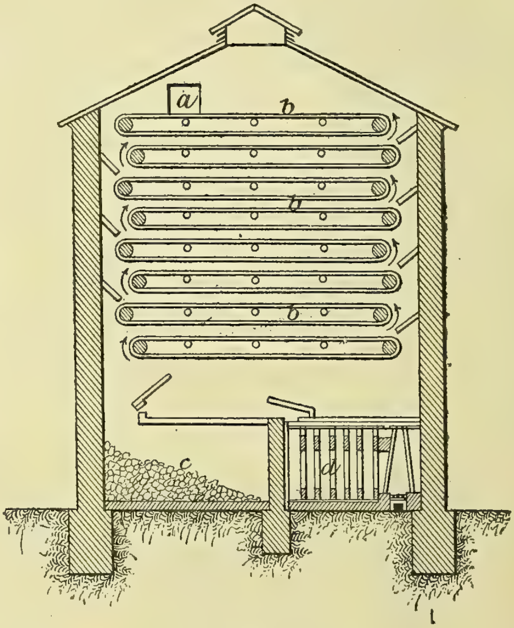
According to Schaer, potato-starch when mixed with 10 parts by weight of a mixture of 2 parts hydrochloric acid sp. gr. 1·12 and 1 part water, forms a jelly which gives off a distinct odour like that of French beans, by which it can easily be detected in presence of other starches.

Rice-starch (Fr., *Amidon de Riz*; Ger., *Reisstärke*).—The grain of the rice-plant (*Oryza sativa*) contains more starch than any other cereal, ranging between 75 and 85 per cent. The plant is raised in enormous quantities in irrigated fields in tropical and sub-tropical countries, notably India, China, Malaysia, Brazil, the S. States of America, and somewhat in Italy and Spain. Mere steeping and bruising do not suffice to separate the starch from the other components of the grain, and recourse is had to caustic alkaline lyes for the purpose. Orlando Jones' method is as follows. A lye of caustic soda or potash is made of such a strength that 350 parts of water contain 1 of alkali; 100 parts of rice are steeped in 500 parts of this dilute lye, in a vessel of copper or tin-lined iron, furnished near the bottom with a draw-off tap fitted with a gauze strainer. The liquor is drawn off after 24 hours, and twice the bulk of pure water is run in; the whole is well stirred, and the water is again drawn off. The clean grain is drained through sieves, ground in a roller-mill or between millstones, and brushed through sieves, the coarse particles which refuse to pass being reground as often as necessary. The fine rice flour is next placed in a similar vessel to the first, with 10 times the quantity of alkaline lye, and the addition of any solid matters which may have settled out from the water used to wash the whole grain; 24 hours' agitation is then given to the mass, and it is allowed 70 hours' perfect rest for subsidence. The lowest layer formed consists of heavy mineral impurities, next follow the fragments of the broken hulls, and finally (topmost) the starch, above which is a brownish-yellow turbid liquid containing the gluten in solution. This last is drawn off by a tin siphon when the operation is adjudged to be complete. The layer of starch is then mixed with water equal to twice the bulk of lye last used, the mass is allowed to subside for an hour, and the milky fluid holding the starch is siphoned off through silken sieves into a series of large vats. The residues from the previous operation are treated again and again, to make them yield the little starch they still contain. The milky liquid in the large vats deposits all its starch during 70 hours' rest. It is again washed with water, drained, and dried like wheat-starch.

1288.



1289.



Berger's process does not differ widely from the preceding. But in addition he has a plan of fermenting the steeped and ground rice for such a period as to permit the removal of the gluten by washing it out. Colman adopts somewhat the same principle, hastening the fermentation by the addition of about 15 per cent. of the sour residue from the wheat-starch manufacture. Ransford follows Jones' method pretty much up to a certain point, but keeps the grain and alkaline lye in motion, either by allowing the lye to run out at the top of the tank and pumping it back through the bottom, or by forcing it into an airtight tank at 20 lb. pressure. A part of the liquor is drained off, and the process is repeated with fresh lye. The completely saturated rice is freed from gluten by pressure through bags, and is then ground and treated for the production of the starch. The American plan differs from all the preceding. The rice is steeped with constant stirring for 18 hours in a caustic soda lye marking 1·75° B. (1·023 sp. gr.), when the dirty yellowish lye is withdrawn, and passed over long inclined tables, to separate the starch-yielding mucus from the lye. The grain, thus softened so as to be easily bruised between the fingers, is repeatedly washed, and then ground to a paste under a stream of very dilute caustic soda lye. Transferred to a vat, it is mechanically agitated for 6 hours, then left to settle for 12 hours, the lye which separates being siphoned off. The thick paste is rotated for ¼ hour in a perforated centrifugal apparatus. The starch-granules arrange themselves here according to their specific gravities; the drained-off liquor may be used again for steeping fresh quantities of rice. The raw starch gathered from the centrifugal is elevated to the highest floor of the building, there stirred up with weak lye to make a "milk," which is passed through cylinder-sieves to washing-out vats on a lower floor, and thence flows to the depositing-vats on the ground floor, where it settles till firm, requiring 24–36 hours. After the clear liquor has been drawn off, the starch is stirred up with water, and passed through the centrifugals. These last should have closed sides, and it is even then doubtful whether their use is advantageous. The starch is rendered almost perfectly dry, but the pieces acquire a rough surface when broken up, and their form renders them unsuitable for making crystal starch.

Sago.—Sago is the amylaceous matter extracted from the pith of several palms; the most important are *Metroxylon Sagu* and *M. Rumphii*; the former is abundant in Sumatra, and grows wild also in Java, Borneo, Celebes, and Malacca; in the Moluccas, it is probably only cultivated; and it does not reach so far east as New Guinea and the neighbouring islands. *M. Rumphii*, which differs from *M. Sagu* in the leafstalk being armed with numerous straight brown spines 1 in. long, has a more eastern range, being abundant in the W. parts of New Guinea, the Moluccas, Mindanao, Gilolo, Ceram, and Amboyna; but is not known to occur in Timor, or westward of Celebes, and is thus absent from Sumatra and Java. Other palms yielding sago in less commercial quantity are *Phœnix farinifera* in Singapore, *Corypha Gebanga* in Java, *Caryota urens* in Mysore, *Borassus flabelliformis* and *Arenga* [*Saguerus*] *saccharifera* in other parts of India. In Malabar, a sort of sago is prepared from the seeds of *Cycas circinalis*, and in Japan from *C. revoluta*; but these do not enter into English commerce. *Metroxylon Sagu* grows in swamps, or in wet hollows on the rocky slopes of mountains; while *M. Rumphii* is a littoral species, forming dense impenetrable belts on the shores of islands. The former is readily propagated from offsets, but seed is generally unproductive. The advance in the price of and demand for the article is causing the Malays to greatly extend the plantations. For making sago, a full-grown tree is selected just before it is going to flower, which it only does when 10–15 years old, and then immediately dies.

In Ceram, it is cut down close to the ground, the leaves and leafstalks are cleared away, and a broad strip of the bark is removed from the upper side of the trunk as it lies upon the ground. This exposes the pithy matter, which is of a rusty colour near the bottom of the tree, but pure white higher up; it is about as hard as a dry apple, but with woody fibres running through it about ¼ in. apart. This pith is cut or broken down into a coarse powder by means of a tool constructed for the purpose—a club of hard and heavy wood, having a piece of sharp quartz rock firmly imbedded in its blunt end, and projecting about ½ in. By successive blows of this, narrow strips of the pith are cut away, and fall into the cylinder formed by the bark. The whole trunk is thus progressively cleared out, leaving a skin not more than ½ in. in thickness. This material is carried away (in baskets made of the sheathing bases of the leaves) to the nearest water, where a washing-machine is put up, which is composed almost entirely of the sago tree itself. The large sheathing bases of the leaves form the troughs, and the fibrous covering (coir) from the leafstalks of the young coco-nut (see p. 939), the strainer. Water is poured on the mass of pith, which is kneaded and pressed against the strainer till the starch is all set free and has passed through, when the fibrous refuse is thrown away, and a fresh basketful is put in its place. The water charged with sago-starch passes on to a trough, with a depression in the centre, where the sediment is deposited, the surplus water trickling off by a shallow outlet. When the trough is nearly full, the mass of starch, which has a slight reddish tinge, is made into cylinders of about 30 lb. weight, covered with sago leaves, and in this state is sold as raw sago. Boiled with water, this forms a thick glutinous mass, with a rather astringent taste, and is eaten with salt, limes, and chillies. Sago-bread is made in large quantities, by baking it into cakes in a small clay oven. According to Crawfurd and Blume, 500–800 lb. of sago are derived from a single tree.

In Sumatra, the felled stems are cut into pieces 3–5 ft. long, from which the outer bark is removed. After lying some days in the shade, they are taken indoors, and rasped into coarse meal with huge graters. The meal is then placed on a cloth stretched over a tub, water is poured on, and the mass is kneaded. The starch passes through with the water, collects in a receptacle, and is removed and dried, forming sago-meal.

The process of preparation in Borneo closely resembles that current in Ceram. Borneo is the head-quarters of sago-culture, the territory of Saráwak alone furnishing more than half the sago produced in the whole world. The palm flourishes on the marshy banks of the rivers all along the Saráwak coast to about 20 miles inland. Very large quantities are brought down from the Limbang, and other rivers in the interior. It is sent down in the raw state, and is manufactured into flour at two Chinese factories near Brunei, and three in Labuan. The exports from Borneo in 1879 were 20,000 tons, value about 161,432*l.* This was almost entirely sago-flour, the quantity of raw sago being very small, and of pearl still less. As seen in commerce, sago is usually in the form of grains. These are prepared by different methods in different localities, but the principle is the same in all, viz. that of mixing the meal into a paste with water, and rubbing it through suitable sieves to granulate it. It is made in a spherical form in New Guinea, according to Forrest, by allowing the sago, as it drops from the sieves, to fall into a shallow iron pot held over a fire. Blume states that in Singapore it is made by the Chinese in a similar way, the grains being constantly turned during the process. A factitious sago is prepared in Europe from potato-starch; the fraud is readily detected by the microscope.

Our imports of sago and sago-flour in 1880 were 377,025 cwt., 304,754*l.*, from the Straits Settlements; 4643 cwt., 3581*l.*, from other countries; total, 381,668 cwt., 308,335*l.* Our re-exports in the same year were: 10,954 cwt., 9224*l.*, to Denmark; 17,357 cwt., 14,391*l.*, to Germany: 14,006 cwt., 13,006*l.*, to other countries; total, 42,317 cwt., 36,621*l.* Our direct imports from Borneo were 5735 cwt., 3993*l.*, in 1876. The approximate London market values of sago are:—Pearl, small, 17–20*s.* a cwt.; medium and large, 19*s.*–21*s.* 6*d.*; flour, 16*s.*–21*s.* 6*d.*

Tapioca.—Tapioca is derived from several species of *Manihot* [*Jatropha*, *Janipha*], chiefly the bitter or poisonous (*M. utilissima*), the sweet cassava, manioc or mandioc (*M. Aipi*), and *M. Janipha.* They seem to be natives of Brazil, but are largely cultivated also in Guiana, Venezuela, W. Africa, and the W. Indies, as well as in S. India and Malaysia. The bitter kind is propagated by cuttings from the ligneous part of the stem, planted in rich dry soil. It is more productive than the sweet species, which latter will grow in almost any soil, though best in such as is suited to the former. The tubers are ready for digging up in 6–12 months, according to the variety. The volatile poison contained in the juice of the bitter kind is first removed in a measure by pressing the grated root, the operation being completed by the subsequent heating passed through. There are two modes of preparing this starch. In the "wet" method, the grated root is placed in water for 4–6 days, then kneaded with water, and pressed to extract the juice. The fecula is sifted and baked in earthen ovens, some fresh manioc paste, which has fermented, being always added. In the "dry" process, the root is rasped by hand, water is added, and it is put to be pressed; after drying and sifting, it is baked. The fecula deposit is washed 3 times and sun-dried. The collected starch, heated on iron plates, becomes partially cooked, and agglomerates in small, hard, irregular lumps, constituting tapioca. In British Guiana, the juice is expressed from the grated root by means of a cylindrical squeezer, called a *matapi*, made from the *ita*-palm (*Mauritia flexuosa*). By attaching one end of the filled bag to a beam, and suspending a weight from the other end, the contents of the bag are compressed by its elongation, and the juice runs out. Pearl tapioca is likewise factitiously prepared from potato-starch. The concentrated juice of the bitter cassava is the basis of the well-known W. Indian sauce called "pepper-pot."

The culture of the plant is inexpensive, and the product is highly remunerative, so that the growth of the plant is becoming very general throughout the tropics. Brazil exported about 7 million *litres* (of 1¾ pints), value 26,050*l.*, in 1871. Dominica exported 246 bush., 63*l.*, in 1872; 2242 bush., 324*l.*, in 1878. Brunei (Borneo) shipped 413 dol. worth to Singapore in 1879. The approximate London market values are:—Rio, 3–6*d.* a lb.; Penang and Singapore, 2⅛–3½*d.*; flour, 1⅜–2⅝*d.*; pearl, 18–30*s.* a cwt. Rio tapioca is whiter than that of Bahia.

Wheat-starch (Fr., *Amidon de Blé*; Ger., *Weizenstärke*).—The ripe grain of the wheat-plant (*Triticum vulgare*) contains 50–75 per cent. of starch. There are three chief methods for preparing wheat-starch, based on different principles:—(1) By acetous fermentation, (2) without fermentation, (3) from flour.

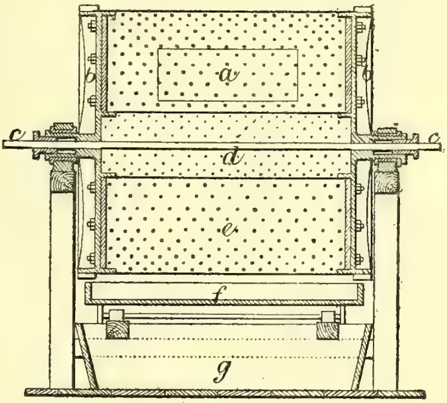
The first plan, which is still in wide use where flour-mills are taxed, labours under the disadvantages that the gluten is destroyed for all practical purposes, and that noxious vapours and foul liquids are largely produced. The wheat is first soaked in "steeping-troughs," capacious tanks of wood, iron, masonry, or concrete, arranged so as to be readily supplied with clean water, and as readily drained of foul liquors, and maintained at a temperature of 12½°–15° (54½°–59° F.). The tank has a strainer-tap for drawing off the foul liquid, and a manhole near the bottom for withdrawing the grain. The tank is half-filled with pure soft water; some of the grain is introduced, and thoroughly stirred up; the hulls, empty grains, and rubbish are skimmed off. This is repeated with new quantities of grain, and water is let in till it rises 2–3 in. above the grain. This water is generally used at a temperature of 10°–12½° (50°–54½° F.), but the operation may be much hastened by employing it at 30°–38° (86°–100½° F.). The duration of the steeping depends much upon the temperature, and upon the character of the water and grain respectively; but commonly amounts to four days in summer and 10–11 in winter. The foul water is drained off, and the soaked mass is washed clean by running in fresh water, and allowing it to drain off for several hours. The grain is then withdrawn at the manhole for bruising. It is necessary to watch that the water does not become sour by the fermentation of extracted matters.

The bruising is very simply performed in a roller mill, the iron rods being adjustable, and a smaller roll revolving above, and serving to regulate the feed. The mill must be set so that it will bruise every grain without crushing the starch granules.

The bruised grain is conveyed for fermentation to large oaken cisterns, which, when new, require to be filled with boiling water for three days to extract the tannic acid. For fermentation, the grain is stirred up with pure water in summer, or soured water in winter, the temperature is maintained at about 20° (68° F.), and the operation lasts some 14 days. During its continuance, the mass is well stirred up. Finally the scum subsides, the surface becomes covered with a fungus (*Penicillium glaucum*), and the mass is "ripe." The result of the fermentation is that the gluten has been so far decomposed as to liberate the starch granules; care must be taken to prevent its overstepping this limit, and affecting the starch granules themselves.

The impure liquor is drawn off from the starch mass, and the latter is transferred to washing-drums (Fig. 1290) for evaporating the starch from the associated impurities. The side-walls *b* of the drum are of wood with iron spokes, the drum itself being a perforated copper plate *e*; a perforated pipe *c* passes through the stuffing-boxes of the drum, and is surrounded by a second casing *d*, also perforated. The drum is emptied and filled by the door *a*. The starch-milk flows from the drum into the box *f*, which runs on rollers, and thence into the depositing-tank *g*.

1290.

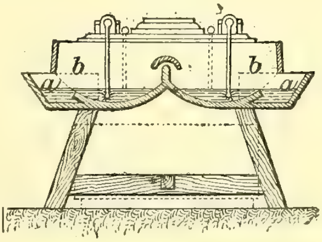


Here the gradual separation of the starch takes place under the influence of agitation and subsequent rest. All but the starch, which forms the lowermost layer, is removed. The starch is then passed through very fine hair sieves, and again stirred up with pure water, and again allowed to deposit after some agitation. It is more convenient to effect the sifting under water. The final deposition takes place in oblong troughs, with convenient taps for letting off the liquids. The refining is not carried beyond the point when the starch ceases to show an acid reaction on litmus-paper. The washing is frequently done in centrifugal machines. Lastly, the starch is dried, first partially by laying the cakes under bricks or gypsum slabs, or by means of air-pumps, and completely in a drying-room at 60° (140° F.).

In preparing wheat-starch without fermentation, the grain is steeped, bruised, and washed, the last operation being best done in a centrifugal machine. The process is not a general one, in spite of its affording the gluten as a by-product.

The preparation of starch from wheat-flour (Martin's method) has many advantages over the ordinary plan. The flour is kneaded into a stiff dough with water, and, after one or two hours, the dough is washed in a fine sieve under a jet of water till all the starch has escaped as a milky fluid. The washing is best effected by a machine such as is shown in Fig. 1291. The troughs *a* contain water, and are replaced at *b* by wire cloth drawn over a wooden frame. Grooved wooden rollers are made to move across the bottom of the troughs, while constant jets of water play upon the dough. About one hour suffices for liberating the starch from 2 lb. of dough. The starch-milk flows off by a pipe into a receiver. The gluten is freed from surplus water by kneading under the rollers, and is then removed for utilization as food.

1291.



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SUGAR (Fr., *Sucre*; Ger., *Zucker*).

The term "sugar" was originally employed and intended to classify all substances having a sweet flavour, and thus came to be used almost indiscriminately for cane-sugar, fruit-sugar, sugar (acetate) of lead, and other bodies possessing that property. At present, in a general sense, it is reserved almost exclusively to denote cane- and beet-sugar (true crystallizable sugar). In chemistry, the word "sugar" is applied generically to a large class of organic bodies intermediate between starch and alcohol, termed "carbohydrates," each having 6–12 atoms of oxygen and hydrogen combined in the proportion to form water; they are nearly allied to, and may be considered as derivatives of, the hexatomic alcohols ($C_6H_{14}O_6$), of which, mannite may be taken as a type. Indeed, mannite, which can hardly be strictly classed as a true sugar, may be artificially formed from glucose ($C_6H_{12}O_6$) by treatment with sodium amalgam, the glucose thereby taking up 2 atoms more of hydrogen, and becoming converted into mannite :—

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} + 2\,H = \underset{\text{Mannite.}}{C_6H_{14}O_6}$$

Although the hexatomic alcohols are not to be regarded as true sugars, still, as each of them possesses a marked saccharine flavour, and presents some of the other characteristics of the true sugars, it will be convenient and instructive to include them in the subjoined tabular classification :—

CARBOHYDRATES.

Isomeric Saturated Hexatomic Alcohols. $C_6H_{14}O_6$.	Isomeric Glucoses. $C_6H_{12}O_6$.	Isomeric Saccharoses. $C_{12}H_{22}O_{11}$.
Mannite, mannitol.	Sucro-dextrose, dextrose, glucose, diabetic sugar.	Cane-sugar, saccharose, sucrose.
Dulcite, dulcitol.	Sucro-lævulose, lævulose, lævo-glucose.	Milk-sugar, lacton, lactose, lactine.
Isodulcite, isodulcitol.	Lactose, galactose.	Starch-sugar, amylon, maltose.
Sorbite, sorbitol.	Arabinose, pectinose.	Mycon, mycose, trehalose.
Pinite, pinitol.	Eucalyptose.	Eucalypton, melitose.
Quercite, quercitol.	Sorbin.	Meleziton, melezitose.
Inosite, inosol.		Parasaccharose.
Dambose.		Synanthron, synanthrose.
Bornesite.		
Dambonite.		

The properties by which the members of these groups may be distinguished are mainly :—(1) By boiling with acids (even dilute), the hexatomic alcohols and the glucoses are but little affected, while the saccharoses are converted into glucoses; (2) the varying powers possessed by many of their solutions, particularly the glucoses and saccharoses, in rotating the vibration-plane of a ray of polarized light; (3) the tendency of the glucoses to enter into fermentation, while the hexatomic alcohols are unfermentable, and the saccharoses are either unfermentable, or only partially fermentable and with great difficulty; most of the last, however, are converted into glucoses by the action of ferments, some of which, such as diastase (a principle formed during the germination of seeds) and synaptase (a principle found in almonds and other fruit-kernels), have special effects. The saccharoses are also converted into glucoses by the saliva, and the juices of the stomach and intestines; and some, as cane-sugar, merely by prolonged heating or boiling in water. Some other ferments, such as *Torula cerevisiæ* and *Penicillium glaucum*, seem to possess the property of converting some saccharoses into glucoses, before promoting the special fermentations produced by their propagation. The fermentable sugars ($C_6H_{12}O_6$) which are capable of direct vinous fermentation are invert sugar (a mixture of dextrose and lævulose), dextrose, lævulose, galactose, maltose.

The members of the first group (hexatomic alcohols) demand no further consideration here. The most important commercially is mannite (see Drugs—Manna, pp. 817–8). The members of the second group (isomeric glucoses) will be spoken of generically at greater length, and the principal ones are specially dealt with under Honey (pp. 1127–30), Drugs—Manna (p. 810), Fruit (pp. 1022–9), Beverages—Wine (pp. 432–50), and sub-sections of the present article.

Invert sugar ($C_6H_{12}O_6$) can be produced from crystallizable sugar by the action of acids, diastase, heat, salts, &c. It is easily fermentable, forms salts with metallic bases, is found in the juices of many plants, and is present in very large proportion in the juice of unripe sugar-cane; it is manufactured on a large scale from grain or starchy materials by treatment with a mineral acid, and conversion with high-pressure steam (see Starch-sugar); as thus prepared, it is uncrystallizable, of a slightly sweetish flavour, and can be concentrated to a thick jelly or to a solid state; heated with a solution of cane-sugar, it converts nearly its own weight of that substance into the uncrystallizable form; with alkalies, it darkens in colour, and forms soluble salts with them; it reduces an alkaline solution of a cupric salt; as a syrup, it is almost colourless, and, in the solid form, the colour varies according to the care taken in its preparation. The two bodies of which it is composed, namely dextrose or dextro-glucose and lævulose or lævo-glucose, differ in rotatory power, and in other particulars; they are, however, seldom met with in a separate state.

Dextrose ($C_6H_{12}O_6$) rotates a ray of polarized light to the right. It may be obtained in the form of needle-shaped crystals by the evaporation of an alcoholic solution; when freshly prepared, its rotatory power is 112°, but after standing for some time, or immediately on heating, the rotation sinks to 56°, and remains constant; it is insoluble in ether, soluble in alcohol, and gives no coloration when mixed with concentrated sulphuric acid; with alkalies, on the application of heat, it turns brown; it reduces an alkaline solution of a cupric salt, and forms with metallic bases, compounds called glucosates; when heated to 170° (338° F.), it gives off one atom of water; by increasing the temperature, it turns brown, and is subsequently converted into caramel.

Lævulose is isomeric with dextrose, but rotates a ray of polarized light to the left; its molecular rotatory power, which varies with the temperature, according to Dubrunfaut, is $[\alpha]j = -53°$ at 90° (194° F.), $-$ 79·5 at 52° (125·6° F.), $-$ 106 at 14° (57·2° F.). It is a colourless, uncrystallizable syrup; on the application of heat, it behaves much in the same way as dextro-glucose. It may be prepared by inverting cane-sugar with hydrochloric acid, and adding excess of calcic hydrate; the liquid after some time solidifies, and the solid mass, when submitted to pressure, yields a solution of a calcium salt of dextro-glucose together with calcium chloride; after washing the cake of lævo-glucose with water, and treating with oxalic acid, a solution of lævo-glucose is obtained.

Maltose, according to O'Sullivan, is a crystalline body yielding 50 per cent. of its weight of alcohol when fermented with yeast. It is formed by the action of malt-extract on starch; its specific rotatory power is twice that of cane-sugar (147·6). 100 parts correspond to 77·32 of cupric oxide, being equal to 65 parts of invert sugar. By boiling with acids, it is converted into dextrose.

Those members of the third group (isomeric saccharoses) which are objects of manufacture will be described in detail under their special heads; others are dealt with under Drugs—Ergot, p. 810, Manna, p. 818.

It may here be explained that "barley-sugar" is pure sugar melted by heat, and allowed to solidify to an amorphous mass instead of crystallizing. "Sugar-candy" is a solution of sugar crystallized by very slow evaporation, the crystals being unusually large, and centred around threads suspended in the liquid for the purpose of forming nuclei. "Molasses" is the dark-coloured, impure liquid, consisting of a mixture of crystallizable and uncrystallizable sugar, coloured by caramel (see pp. 598–9), and containing the greater part of the organic matters separated in the processes of making and refining cane- and beet- sugars. "Syrup" or "golden syrup" is the molasses obtained by washing and "machining" the higher classes of refined sugar. "Glucose" is applied commercially only to artificial starch-sugar; in analysis, it signifies all uncrystallizable sugar found in cane-sugars: to avoid confusion, the term "uncrystallizable sugar" will be employed throughout this article to denote all forms of uncrystallizable or very slightly crystallizable sugar—(the very weak crystallizing power of dextrose and lævulose causes them to be called *un*-crystallizable)—met with or produced in the course of preparing crystallizable sugar, and the special terms glucose, starch-sugar, will be reserved for their special application. The commercial sugars, whose production and manufacture will receive detailed description in this article, will take the following order:—Beet-sugar, Cane-sugar, Maple-sugar, Melon-sugar, Milk-sugar, Palm-sugar, Sorghum- and Maize-sugar, Starch-sugar and other Glucoses. These will be followed by sections on Sugar-refining, Summary of Patents, Analysis, Production and Commerce, Bibliography.

Beet-sugar (FR., *Sucre de Betteraves*; GER., *Rübenzucker*). CULTIVATION.—The beetroot (*Beta vulgaris*), indigenous to Europe, is cultivated in France, Germany, Belgium, Holland, Scandinavia, Austria, Russia, and to a very small extent in England, and recently established in Canada, the United States, and New Zealand. There are many varieties. The most important to the sugar-maker is the white Silesian, sometimes regarded as a distinct species (*B. alba*); it shows very little above ground, and penetrates about 12 in.; it has a white flesh, the two chief forms being distinguished by one having a rose-coloured skin and purple-ribbed leaves, the other a white skin and green leaves. Both are frequently grown together, and exhibit no marked difference in sugar-yielding qualities.

Good sugar-beets possess the following broad characteristics:—(1) Regular pear-shaped form and smooth skin: long, tapering, carrot-like roots are considered inferior; (2) white and firm flesh, delicate and uniform structure, and clean sugary flavour: thick-skinned roots are spongy and watery; those with large leaves are generally richer; (3) average weight 1½–2½ lb., neither very large nor very small roots being profitable to the sugar-manufacturer; as a rule, beets weighing more than

3½ lb. are watery, and poor in sugar; and roots weighing less than ¾ lb. are either unripe or too woody, and in either case yield comparatively little sugar; the sp. gr. of the expressed juice, usually 1·06–1·07, even reaching 1·078 in English-grown roots, indicating over 14 per cent. of crystallizable sugar, is the best proof of quality; juice poor in sugar has a density below 1·060; (4) in well-cultivated soil, the roots grow entirely in the ground, and throw up leaves of moderate size.

The improvement of the sugar-beet has long been studied by Continental agriculturists. The comparative values of the chief new sorts shown at the Paris Exhibition may be thus tabulated, premising that the figures given are not attained on a working scale :—

Name.	Gross yield per acre.	Sugar in 1 gal. of juice.	Sugar yield per acre.	Working yield of Sugar.	
				Per ton.	Per acre.
	lb.	lb.	lb.	lb.	lb.
German	50,776	1·54	6925	226	4541
Green-neck	67,936	1·42	8496	177	4775
Rose-neck	65,560	1·47	8562	186	4835
Grey-neck	72,072	1·32	8333	152	4417
Vilmorin's	36,168	1·90	6103	296	4144

The last-named is most esteemed where the duty is levied on the roots (Germany and Russia); it gives 15–18 per cent. of extremely pure juice.

Composition of the Roots.—Internally the root is built up of small cells, each filled with a juice consisting of a watery solution of many bodies besides sugar. These include several crystallized salts (most of which are present in minute traces only), such as the phosphates, oxalates, malates, and chlorides of potassium, sodium, and calcium, the salts of potash being by far the most important; and several colloid bodies (albuminous [nitrogenous] and pectinous compounds); as well as a substance which rapidly blackens on exposure to the air. The greater part of the sugar in ripe beets is crystallizable, and, when perfectly pure, is identical in composition and properties with crystallized cane-sugar; but it is more difficult to refine this sugar so as to free it from the potash salts, and commercial samples have not nearly so great sweetening power as ordinary cane-sugar. Beets contain no uncrystallizable sugar: the molasses produced in beet-sugar manufactories is the result of changes which cannot be entirely avoided in extracting the crystallizable sugar.

Following are analyses by Voelcker of roots grown near Lavenham, Suffolk :—

Description	Green top, white skin.	Red top, rose-coloured skin.	White pear-shaped root.	Long red root.	Long red root.	Pear-shaped white root.	Small red top.	Pear-shaped white root.
Weight of root ..	2¾ lb.	2 lb. 4½ oz.	1½ lb.	2 lb.	1¾ lb.	2 lb. 5 oz.	1 lb. 4¾ oz.	2 lb. 12¼ oz.
Sp. gr. of juice ..	1·0637	1·0689	1·058	1·0612	1·0628	1·0589	1·0659	1·0643
At a temp. of	64° F.	64° F.	62° F.	62° F.	..	..	58° F.	58° F.
Moisture	83·11	82·72	83·03	83·43	82·70	82·27	81·76	83·34
Albuminous compounds *	1·25	1·44	1·71	1·53	1·23	1·08	2·13	2·12
Crude fibre (pulp) ..	3·43	3·38	4·31	3·49	3·60	3·73	3·77	3·04
Crystallizable sugar	10·51	10·94	9·31	10·04	10·72	11·14	10·55	9·74
Pectin, colouring matter, &c.	0·63	0·45	0·60	0·50	0·68	0·74	0·70	0·52
Mineral matter (ash)	1·07	1·07	1·04	1·01	1·07	1·04	1·09	1·24
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	0·200	0·231	0·275	0·245	0·197	0·173	0·341	0·340

Climate.—The mean temperature of the Continental beet-growing districts, and of those localities in England where beets may be cultivated for sugar-making purposes, is about 16½°–18° (62°–65° F.). The formation of the sugar is favoured not so much by a hot summer as by dry weather and unclouded sky during autumn: hence the root succeeds better in N. France and N. Germany than in Central France and S. Germany; hence also the prospects of remunerative culture in Canada and New Zealand, and the failure in Australia. Nothing is so conducive to heavy crops as an abundance of rain during the first 2 months' growth of the plant. It would thus appear that the E., S.-E. and N. counties of England, with many localities in Scotland, and a portion of Ireland, are, so far as climate is concerned, well suited to the cultivation of the sugar-beet; but it has hitherto been very little encouraged by agriculturists.

Soil.—The best soil for beet contains a fair proportion of organic matter, is neither too stiff nor too light, and crumbles down into a nice friable loam; it must be capable of being cultivated to a depth of at least 16 in. The subsoil should be thoroughly well drained, and rendered friable by autumn-cultivation and free admission of air. A deep friable turnip-loam, containing fair proportions of clay and lime, appears to be the most eligible land for sugar-beets. Lime is a very desirable element. Well-worked clay-soils, especially calcareous clays, are well adapted, if properly drained and of sufficient depth. Peaty soils and moorlands are quite unsuitable, as well as lands which are too dry, like the thin gravelly soils resting on siliceous gravel sub-soils, or too wet and cold, like many of the thin soils above impervious chalk marl.

Speaking generally, the best soils for sugar-beet are precisely those on which other root-crops can be grown to perfection, that is, land which is neither too heavy nor too light, which has a good depth, is readily penetrated by the roots, and naturally contains lime, potash, clay, and sand, as well as organic matter, in such proportions as in good friable clay-loams. An analysis of the soil should be made previous to planting it with the sugar-beet, as the salts presented in solution in the soil will pass into the juice, and greatly interfere with the processes of sugar manufacture. Certain soils may be at once indicated as unsuitable: they are clover-land, recent sheep-pastures, forest-land grubbed during the preceding 15 years, the neighbourhood of salt-works, volcanic and saline soils of all kinds. The beet requires a certain supply of potash and soda salts in the soil, but if these are present in excess, as in recent forest-land, the juice does not work well, nor give its proper yield of sugar.

Manures.—Sugar-beets should be grown with as little farmyard manure as possible; when dung has to be used, as in the case of very poor soils, it should be applied in autumn, or as early as possible during the winter months. The effect of heavy dressings of animal nitrogenous matters or ammoniacal salts, is to produce abundance of leaves, and big watery roots; the latter are comparatively poor in sugar, and contain potash salts derived from the animal matters, which greatly interfere with the extraction of sugar in a crystallized state. Common salt, and saline manures in general, though useful in moderate doses (2–3 cwt. per acre on light soils), should be avoided on the majority of soils, for sugar-beets grown on soils highly manured with common salt produce juice largely impregnated with salt, which is dreaded by the manufacturer even more than albuminous impurities, and nearly as much as excess of potash salts.

If the land is in good condition, containing sufficient available nitrogen to meet the requirements of the crop, neither guano nor sulphate of ammonia should be used. They largely increase the weight of the produce per acre; but heavy crops are generally poor in sugar, and furnish a juice that presents much difficulty to the manufacturer. If the land is very poor, and if farmyard manure cannot be obtained and be applied in autumn, 3–4 cwt. of Peruvian guano, or 2 cwt. of sulphate of ammonia, mixed with 2 cwt. of superphosphate of lime, per acre, may be sown broadcast in autumn, and 2 cwt. more of superphosphate may be drilled in with the seed in spring. Superphosphate of lime and bones are excellent for sugar-beets, and never injure the quality of the crop, like the indiscriminate use of ammoniacal manures. On light soils, in which potash is often deficient, the judicious use of potash salts has been found serviceable, but only in conjunction with superphosphate and phosphatic guanos.

Analyses of sugar-beet ash show that this crop takes from 1 acre of land:—Potash, 161·92 lb.; nitrogen, 105·60; phosphoric acid, 40·48; lime, &c., 31·68. The injurious consequences of a heavy spring-dressing of dung for sugar-beets are shown in the annexed analyses, representing the composition of 2 very large white Silesian beets grown in Suffolk:—

	A.	B.
Weight of root	11 lb. 6 oz.	6 lb. 8 oz.
Sp. gr. of juice at 18° (65° F.)	1·0431	1·0553
Moisture	92·58	88·13
Albuminous compounds*	1·40	2·16
Crude fibre [pulp]	1·73	2·74
Crystallizable sugar	2·22	4·82
Pectin, &c.	0·47	0·44
Mineral matter [ash]	1·60	1·71
	100·00	100·00
* Containing nitrogen	0·225	0·347

Sowing.—The best time for sowing beetroot in England is the beginning or middle of April. If sown too early, the young plants may be partially injured by frost; if later than the first week in

May, the crop may require to be taken up in autumn, before it has had time to get ripe. About 10–12 lb. of seed is required per acre. As regards the width between the plants, generally speaking, the distance between the rows and from plant to plant should not be less than 12 nor greater than 18 in. Should the young plants be caught by a night's frost, and suffer ever so little, it is best to plough them up at once and re-sow, for they are certain to run to seed, and are then practically useless for the manufacture of sugar. Sugar-beets require to be frequently horse- and hand-hoed. As long as the young plants are not injured, the application of the hoe from time to time is attended with great benefit to the crop. It is advisable to gather up the soil round each plant, in order that the head may be completely covered with soil. Champonnois' researches point to the advantage of planting in ridges, by which the supply of air to the roots is greatly facilitated.

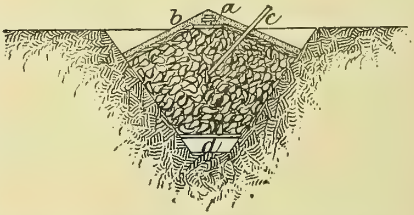
On the Continent, the conditions best calculated to ensure the roots possessing the characters most desirable from a sugar-maker's point of view have been much studied. They are chiefly as follows:—(1) Not to sow on freshly-manured land: it is eminently preferable not to manure for the beet crop, but to manure heavily for wheat in the preceding year; (2) not to employ forcing manures, nor to apply manure during growth; (3) to use seed from a variety rich in sugar; (4) to sow early, in lines 16 in. apart at most, the plants being 10–11 in. from each other: there will then be 38,000 beets on an acre, weighing 21–28 oz. each, or 52,800–70,400 lb. per acre; (5) to weed the fields as soon as the plants are above ground, to thin out as early as possible, and to weed and hoe often, till the soil is covered with the leaves of the plants; (6) never to remove the leaves during growth; (7) finally, not to take up the roots, if it can be avoided, before they are ripe, the period of which will depend upon the seasons.

Good seed may be raised by the following means. The best roots, which show least above ground, are taken up, replanted in good soil, and allowed to run to seed. This seed is already good; but it may be further improved by sowing it in a well-prepared plot possessing all the most favourable conditions; the resulting plants are sorted, set out in autumn, put into a cellar, and in the spring, before transplanting, those of the greatest density, and which will give seeds of the best quality, are separated. These are transplanted at 20 in. between the rows and 13 in. between the feet, which are covered with about 1½ in. of earth. Finally they are watered with water containing treacle and superphosphate of lime, as recommended by Corenwinder.

Harvesting.—Sugar-beets must be taken up before frost sets in. When the leaves begin to turn yellow and flabby, they have arrived at maturity, and the crop should be watched, that it may not get over-ripe. If the autumn is cold and dry, the crop may be safely left in the ground for 7–10 days longer than is needful; but should the autumn be mild and wet, if the roots are left in the soil, they are apt to throw up fresh leaves, and nothing does so much injury. In watching the ripening of the crop, a good plan is to test the sp. gr. of the expressed juice. A root or two may be taken up at intervals, and reduced to pulp on an ordinary hand-grater, the juice obtained by pressing the pulp through calico, and the density observed by a hydrometer. As long as the gravity of the juice continues to increase, the crop should be left in the land. Good sugar-yielding juice has a sp. gr. of about 1·065, rising to about 1·070. Immature roots, cut across, rapidly change colour on the exposed surface, turning red, then brown, and finally almost black. If newly-cut slices turn colour on exposure, the ripening is not complete; but if they remain some time unaltered, or turn only slightly reddish, they are sufficiently ripe to be taken up. The crop should be harvested in fine, dry weather. In order that the roots may part with as much moisture as possible, they are left exposed to the air on the ground before being stacked, but not for longer than a few days, and they need to be guarded against direct sunlight. Perhaps the best plan is to cover them loosely with their tops in the field for a couple of days, then trim them, and at once stack them.

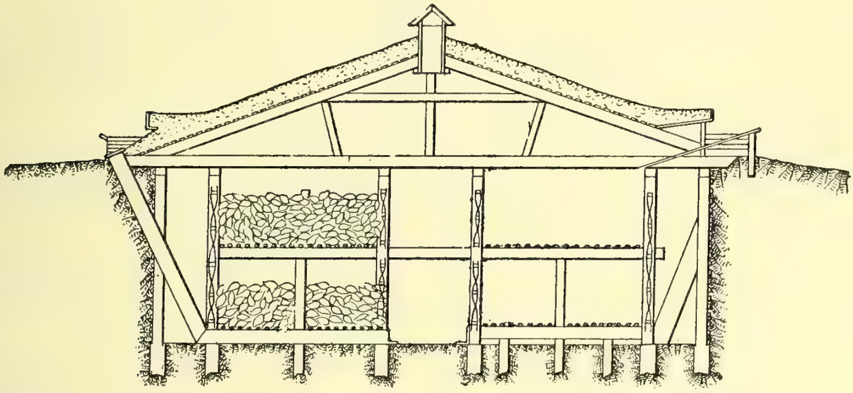
Storing.—For storing roots, especial care should be taken to prevent their germinating and throwing out fresh tops, which is best done by selecting a dry place for the storage ground. They may be piled in pyramidal stacks, about 6 ft. broad at base, and 7 ft. high. At first, the stacks should be thinly covered with earth, that the moisture may readily evaporate; subsequently, when frosty weather sets in, another layer of earth, not exceeding 1 ft. in thickness, may be added. This is essentially the method generally adopted in this country for storing potatoes and mangold.

1292.



In continental Europe and Canada, extra precaution is necessitated by the rigorous climate. In S. Russia, the plan shown in Fig. 1292 is sometimes used. The beets are disposed completely below the surface of the soil, in a trench dug with sharply sloping sides. At about 15 in. from the bottom, is an openwork floor of reeds, on which the beets are piled to within a few inches of the level of the exterior soil. On the top, and following the apex of the heap, is laid a triangular ridge-piece *a*, for the purpose of facilitating evaporation. The whole is covered with a layer *b* of straw and fine earth, the thickness of which is varied according to the indications of the thermometer *c* placed in the centre of the mass. Between the floor of the trench and the openwork floor is a space *d*, communicating with two vertical channels leading to the outer air, thus providing ventilation. The outlets of the channels can be opened and closed at will. The Russians also often employ regular cellars, as shown in Fig. 1293. The structure consists of two storeys, covered with a bed of earth, each furnished with a floor of hurdles or open planking, on which the beets are piled to the depth of about 1 yd. Lateral passages facilitate ventilation, and openings in the roof permit the heated air to escape. The cost of erecting these cellars is heavy, but there is great saving of labour in storing the beets, as it suffices to simply pile them up on the floors. Moreover, the arrangement permits the examination of the contents beyond the indications of a thermometer; and enables any portion to be removed, even during snowy weather.

1293.



Diseases and Enemies.—The insects injurious to beet are principally three,—the beet carrion-beetle, the beet-fly, and the silver-Y moth. The beet carrion-beetle (*Silpha opaca*) gnaws away the leaves till the fibres alone remain, but the roots escape. The egg is commonly laid in putrid matter. The attacks of the grub last from about the 3rd week in May to the end of June; no damage seems to be done by the summer brood of beetles. Remedies are:—(1) sprinkling the plants with a mixture of 1 bush. gas-lime, 1 bush. quick-lime, 6 lb. sulphur, and 10 lb. soot, made into a fine powder, and applied while the dew is on the leaf, this quantity sufficing for about 2 acres; (2) the substitution of superphosphate of lime for farmyard dung; (3) the application of dung, when used, in the autumn instead of the spring.

The beet- or mangold-fly (*Anthomyia betæ*) damages the crops by the attacks of its voracious legless maggots, which feed on the pulp of the leaves, and reduce them to a dry skin. Their worst effects are seen on peat and fen lands, and in wet seasons. A dressing of superphosphate seems to be effectual.

The silver-Y moth (*Plusia gamma*), extending from Abyssinia to Greenland, and met with in China, Siberia, and N. America, occasionally does great damage to the Continental beet-crops, while in the caterpillar state. The latter are large, and consume the leaves rapidly. Dustings of caustic lime, soot, or salt, and drenchings of liquid manure or simple water, are beneficial.

Extraction. Purchase.—In the beet-sugar industry, the manufacturer very seldom grows the whole of the beet that he works up, though he almost invariably raises a considerable proportion. The basis upon which the manufacturer purchases from the grower is a matter of importance to both. It is the interest of the manufacturer to base payment upon the quantity of sugar delivered in the roots. To buy and sell on the weight of roots is unfair to both, taking no account of the quality of the article, and removing all inducement to grow the most highly saccharine kinds. To make an average analysis of a crop, would be very inconvenient; but as the juice is denser according as it is richer in sugar and poorer in other salts, it has been customary to base the value on this, taking for foundation a sp. gr. of 1·055 (7·27° B.), called 5·5 degrees, and raising the price proportionally above that figure. It has likewise been suggested that the price should be subject to a corresponding reduction for juice below 5·5, but this is generally deemed unfair to the grower, as only arising through unpropitious seasons and other causes not within his control.

The "Société Centrale de l'Agriculture du Pas-de-Calais" proposes the following scale:—

Density.	Sugar Yield.	Price.	
		Per 1000 Kilo.	Per Ton.
sp. gr.	per cent.	fr.	*s. d.*
1·045	8	16	12 10
1·050	9	18	14 6
1·055	10	20	16 2
1·060	11	21	17 0
1·065	12	22	17 10

An objection to this scale is that the progressive value is not geometrically increased with the greater richness, whereas the yield of sugar is known to be augmented disproportionately in rich juice. Thus, to produce 100 lb. of sugar will require: 1333 lb. of beetroot at 12½ per cent.; 1593 at 11; 2213 at 9. In other words, while 620 lb. are needed to compensate for the difference between 9 and 11, only 260 are necessary to counterbalance that between 11 and 12½.

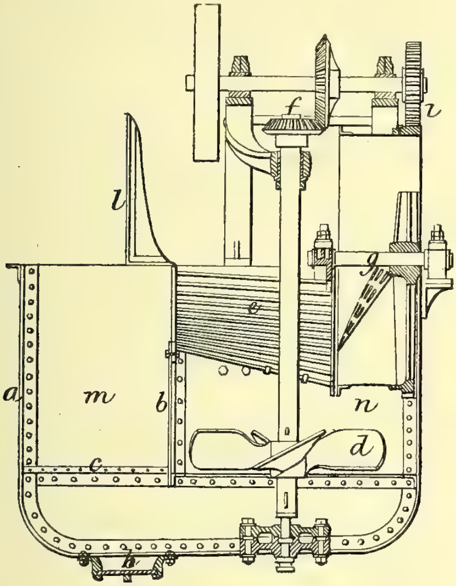
When the roots are delivered at the factory, after having been deprived of leaves, rootlets, and necks (the portion growing above ground), they are weighed, and a "tare" is deducted for earth, badly-trimmed necks, and other useless matters. This is the point at which the manufacturers' and cultivators' interests clash; in Germany, this weight is also the basis of taxation of the industry. When the crop is paid for according to the density of the juice, a certain number of roots are selected as a sample, their pulp is rasped up, and the juice is expressed and tested by a hydrometer. Several instruments have been devised for rapidly dealing with sufficient roots for this purpose, the most important being those of Possoz, Violette, and Thomas.

Transport.—The transport of the roots from the fields to the factory may be performed by rail, road, or river, where such facilities exist; but the rope-tramway system presents many advantages, as it abstracts nothing from the land under cultivation, is very cheap, and can be moved about as circumstances require. The labour, cost, and difficulty of conveying enormous quantities of roots to the factory, where the juice is to be utilized and the pulp returned, have drawn attention to means of transporting the juice alone, which has been independently extracted on the farm producing the beet. A few years since, Linard, of Cambray, introduced a plan of sending the juice to a central factory by means of an underground system of piping, which is gaining favour in France and Belgium. A single factory is thus enabled to work up what would otherwise have to be distributed among several factories, effecting at the same time great economy of transport, fuel, plant, and labour. The juice, obtained by any of the methods to be described later, is received in gauge-tanks, treated with 1 per cent. of lime, and pumped into the cast-iron subterranean conduit, capable of withstanding a pressure of 15 atmos., and of a diameter (varying with the distance) of 2½–5 in. The juice is received at the central factory in large store-tanks. There is no apparent effect upon the pipes after several years' constant use. The set at Cambray takes the juice produced by 10,250 acres of beet.

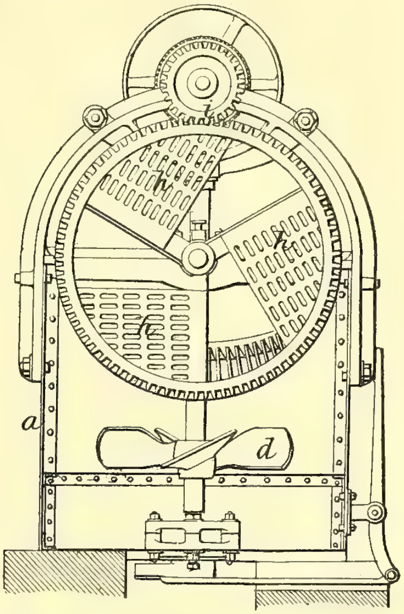
Cleansing the Roots.—The first step towards extracting the juice from the roots is to free the latter from foreign matters. With this object, the roots are conveyed to a room capable of containing 2–3 days' supply. The damage done to machinery by the presence of stones has led to the introduction of "stoning-machines." The stoner invented by Collas, of Dixmude, and made by Lecointe et Villette, is shown in Figs. 1294–5. The tank *a* is divided into two compartments by partitions *b c*, forming between them a right angle, the vertical one *b* constituting a strainer at its upper part, and the horizontal one *c* occupying only about ⅔ of the length of the box, fixed at a certain distance above the bottom, and having a circular central orifice. Therein is placed a horizontal screw *d* with 4 arms, similar to those used in navigation. A horizontal grating is provided in the compartment *m* on the left, in prolongation of the horizontal partition on the right, and an inclined grating *e* in that (*n*) on the right, above the vertical partition. The apparatus being filled with water, and the screw set in motion by the bevel-wheels *f*, a circulatory movement is communicated to the water, which rises in the compartment *m*, passes above the strainer, and, traversing the inclined grating *e*, returns to the compartment *n*, and again comes under the influence of the screw. If beets are thrown into this rapid current in the compartment *m*, the stones rest on the grating or fall to the bottom, while the roots, by virtue of their relatively small sp. gr., are taken up by the current of water on to the inclined grating *e*, and tossed out of the machine by a little drum *g* armed with sloping flanges *h*, and driven by cog-wheels *i*. A trap-door *k* allows the vessel to be emptied of dirty water, and of the mud and stones which collect on the bottom. A vertical panel *l* of sheet iron, placed above the compartment *m*, prevents the beets falling directly on the inclined delivery-grating, and protects the driving-gear from splashings of water. The machine is already employed in several factories, being generally placed after the washer, and performing a second washing, which is especially valuable when the diffusion process is adopted.

The washer, Figs. 1296–7, consists of a perforated sheet-iron cylinder *a*, revolving on its axis in a tank of water *b*. In front of the tank, is bolted a hopper *c*, into which the beets fall; behind is a strainer. The cylinder leaves a space of only about ½ in. at each end of the tank, that the roots may not get wedged in. The washed roots are thrown out by a helical grating *d* placed at the end opposite to the hopper. The rounded bottom of the tank is inclined towards an opening, by which the dirt and rootlets can be discharged. Another form of washer, shown in Fig. 1298, is designed to overcome the disadvantage manifested by the preceding, in requiring frequent stoppages while the water is being changed. It consists of an archimedean screw working in a trough. The beets are fed in at *a*, and are carried by the screw against a descending stream of water in the direction indicated by the arrow, escaping at *b* perfectly clean.

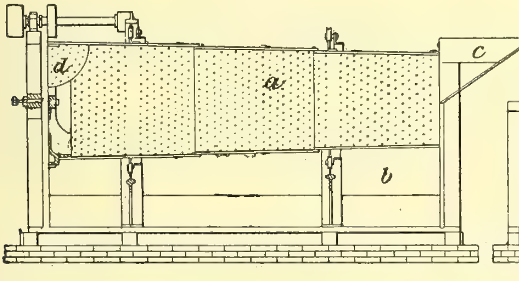
1294.



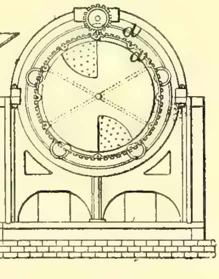
1295.



1296.



1297.

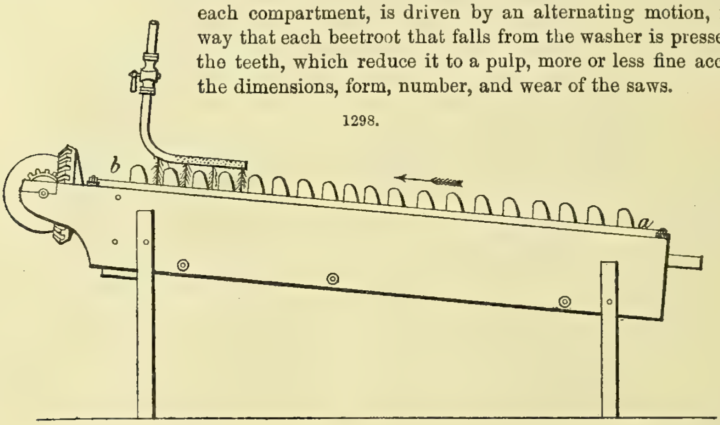


The processes described thus far are of universal application: the stoning and washing of the roots are needful preliminary operations, whatever mode of extracting the juice may be adopted. Here the parallel ends, and it is necessary to classify the succeeding methods of manipulation. They may be grouped under the following heads:—(*a*) Rasping and Pressing, (*b*) Maceration, (*c*) Diffusion.

Rasping and Pressing.—The principles which govern this process are essentially mechanical. The aim of the operations is to first comminute the root so as to effect the rupture of the greatest possible number of cells, and then to separate the liberated but still absorbed juice from the solid matters by means of pressure, whether of a press or of a centrifugal hydro-extractor.

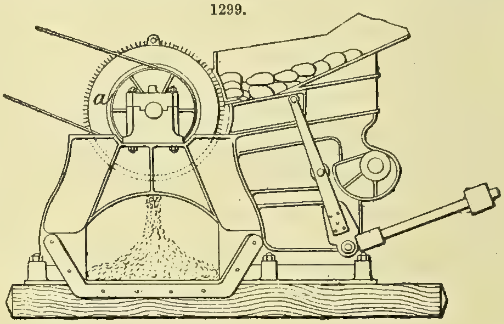
Raspers.—Machines for reducing beets to a pulp are of multitudinous forms, and it would be impracticable to describe all of them. They universally consist of a revolving drum armed with teeth, and differ mainly in having the dentition external in some cases and internal in others. The type of the first class is shown in Fig. 1299. The cylinder *a*, 24 in. diam., has its surface formed by a series of saw-blades (shown full-size in Fig. 1300), separated by wooden washers. The cylinder is divided into 2 or 3 compartments by intermediate false bottoms, and is driven at a speed of 800–1000 rev. a minute. It rotates in front of an inclined table, on which a pusher, placed before each compartment, is driven by an alternating motion, in such a way that each beetroot that falls from the washer is pressed against the teeth, which reduce it to a pulp, more or less fine according to the dimensions, form, number, and wear of the saws.

1298.



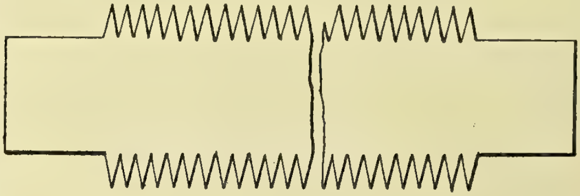
The typical representative of the internal system of grating is Champonnois' rasper, shown under Starch, p. 1824, Fig. 1284. The beets are introduced by the hopper *a*, and are forced by the rapid rotation of the fliers *b* (800–1000 rev. a minute) against the short saw-like teeth of the raspers *c*. Water is at the same time injected at *d*. Fast and loose pulleys are shown at *e f*, and a fly-wheel is fixed on the end of the shaft *g*. The machine is reversed every 6 hours to equalize the wear, still the saws require sharpening after 48 hours' use. The pulp falls into a receptacle beneath.

1299.



Presses.—The pulp obtained from the raspers is carried or pumped up from the cistern in which it has collected, to be submitted to expression. The presses used are of two kinds, alternating (including screw and hydraulic) and continuous. For the hydraulic press, the pulp is placed in woollen sacks, containing 10–12 lb., superposed in the press with their mouths doubled under, and separated by iron plates; about 25 are collected, and the pile is put into a screw-press, called a "preparatory" press, which extracts about 45–50 per cent. of the juice. These pressed sacks are piled anew on the movable plate of a powerful hydraulic press, which takes 50 at a charge. Each preparatory press can supply 4 hydraulic presses, which are ranged around it, so that of the 4 presses, there will be one charging, one commencing to press, one in full pressure, and one discharging, at the same moment. Motion is communicated to the 4 hydraulic presses by 4 pumps mounted on the same bed, and tended by the same workman who directs the pressing. An improvement upon the general form of hydraulic press is that devised by Lalouette, which enables 2 workmen and 1 boy to keep 5 presses at work. These presses turn out about 300 cwt. per 24 hours in the first pressing, and 600 in the second. Hydraulic presses are rapidly falling into disuse in the beet-sugar industry, by reason of the superior merits of continuous presses, and the extended adoption of the diffusion system.

1300.



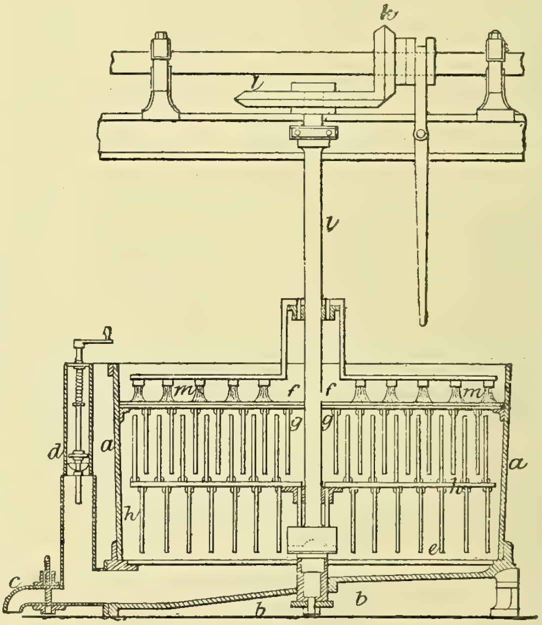
Continuous presses for beet were suggested by the roller-mills used in the cane-sugar industry. But the conditions in the two cases are widely different: the begass of the cane is solid, and readily parts from the juice; whereas the pulp and juice of the beet have a strong tendency to combine, and the roller-surface must therefore be permeable only by the juice. In Poizot et Druelle's press, the pulp passes between two cylinders, carried by endless cloths. The object is to unite the best features of the hydraulic press. To this end, a first gentle pressing is produced against the first cylinder by the elasticity of the principal cloth on which it is borne. Then, encountering a series of 4 little rollers, performing the functions of the preparatory press, it is next seized between the second and first cylinders, and deprived of the maximum quantity of juice. The press has been much improved since it first appeared. Manuel et Socin's press, made by Cail et Cie., has an ingenious modification by which the hair-cloth carrying the pulp is kept of a constant width. Each press, worked by one man, will treat the pulp of 1375–1570 cwt. of beet per diem, requiring scarcely 1 H.P. The juice, filtered through the hair-cloth, is free from pulp. The cost of manipulation is about 4*d.* per ton of root; the yield is 26–28 per cent. of pulp. The juice can only be perfectly extracted by a second pressing. To effect this, two first-pressure presses are used for one second-pressure. The pulp falls from the first into the trough of a screw, where it is mixed with a large quantity of water. Between the second and third presses, is another screw, which raises the softened pulp to the third press for a second pressing. The whole operation only occupies 25–30 seconds. The juice of the second pressing is used instead of water in the raspers, as the rapidity of the work prevents it undergoing any change, so that the juices are sent to the carbonization stage almost at the degree of density which they possessed while in the root, and the pulp retains but little sugar. Champonnois' press is composed of two permeable rollers partially immersed in a cast-iron tank, forming a watertight joint with their bases and with the portion emerging at the surface. The pulp can only escape between the rollers. A pump conveys the pulp leaving the raspers, and forces it into the tank under a pressure of 1–2 atmos. The juice passes out between the rollers, while the exhausted pulp is raked away by two knives, which seize it immediately at the exit, and falls by its own weight in front of the press, inclined for the purpose at 45°. The cylinders are driven in opposite directions. The filtering surface is formed by spiral windings of a triangular thread, the spaces being determined at 0·004–0·008 in. In this way, is produced a filter-surface having narrow openings on the outside and widening inwards. On leaving the press, the juice is received by a sieve, which prevents the loose pulp from mixing with the juice. The press has been further improved in the hands of Cail et Cie., and is now one of the most perfect and least costly in the market. Lebée's press is also composed of two filter-cylinders, in appearance somewhat resembling Champonnois', but essentially different in construction. It is formed of a series of portions of filtering surface, screwed on side by side, and enveloping the cylinder; each portion consists of 10 little strips of copper, curved longitudinally, soldered at the ends, and separated by intervals of 0·004–0·008 in. This press allows the filter-surface to be changed more easily than in the Champonnois press, without removing the cylinders; but it is not so simple. Cuvelier's press, constructed by Lobbedez, has been at work for some years at Louez, near Arras, and gives 28–30 per cent. of pulp retaining very little sugar. Piéron's system has been adopted at the Montigny factory: the preparatory press treats nearly 2000 tons of beetroot per 24 hours; the ordinary first press, nearly 800 tons; and the second press, over 1500 tons. Sufficient has now been said to illustrate the principles and essential features of continuous presses for separating the juice from the pulp of mashed beets. Examples might be multiplied almost indefinitely.

Depulpers.—The term "depulpers" has been applied to a class of apparatus rendered necessary by the inability of the ordinary filters to completely remove the fine pulpy matters from the juice. They are really nothing more than effective mechanical filters. That of Loynes, made by the Cie. de Fives-Lille, is largely used in other industries besides beet-sugar making. Those of Mariolles and Mesnard are constructed by Cail.

Centrifugals.—Centrifugal hydro-extracting machines, which are described under Cane-sugar and Refining, have been tried for separating beet-juice from the pulp of the grated roots. In practice, however, they are incapable of extracting more than 60–65 per cent. of the juice under the most favourable conditions, and consequently they are not superior to hydraulic presses. Their use in this sphere is virtually a thing of the past.

Maceration.—The shortcoming of the expression processes gave an impetus to experiment in other directions, and notably with regard to the dissolving and displacing powers of water when applied to the pulp. One of the earliest plans based upon these principles was the maceration system of Schutzenbach, illustrated in section in Fig. 1301. The essential parts consist of round sheet-iron vessels *a*, the bottom *b* of each being made sloping towards one side, where the liquid can be completely drawn off by taps *c*. If the tap *c* is closed, the liquid rises in the tube *d*, and flows thence by a lateral pipe into a second similar vessel placed at a lower level. Above the bottom *b*, is a false bottom *e*, furnished with a metallic strainer, which retains the solid pulp while the juice escapes. At the top, in *f*, is a second similar strainer, formed in two pieces, and easily removable. The vertical bars *g* suspended from *e* are for breaking up the pulp, and preventing its making a simple rotation, under the influence of the mechanical agitator *h*, attached to the axis *i*, and actuated by the bevel-wheels *k l*. The same axis carries cleaning-brushes *m*, which keep the orifices of the upper grating clear for the passage of air and water; and a similar set perform the same function for the lower strainer. In working, each vessel receives at first a little juice (except at starting, when the juice is replaced by water); the pulp is then introduced, the agitator being meantime kept in motion, or the densest pulp would fall to the bottom, and soon choke the strainer. The speed of the agitator must be carefully regulated: too rapid movement would create a large quantity of froth; too slow would reduce the rapidity of the maceration, and therefore the effective capacity of the apparatus. A speed of 20–24 turns a minute would seem to give the best results. Later, when the juice is partly expressed, the agitator may be left at rest; the ligneous portion of the cells, being lighter than the water, remains on the surface, and has no longer a tendency to choke the metallic diaphragm.

1301.

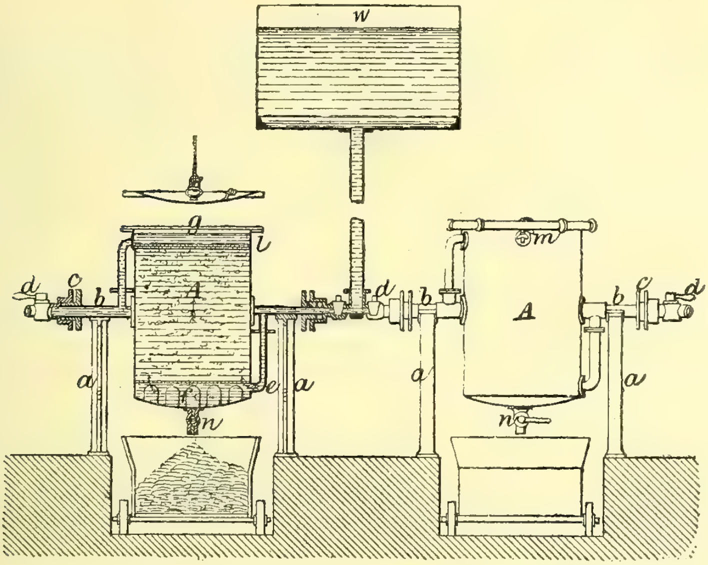


Unfortunately, whatever precautions are taken, a large proportion of pulp always finds its way through the strainer, and these solid matters render the defecation more difficult and imperfect, in consequence of the large quantities of scum to which they give rise. This inconvenience is partially remedied by passing the juice, on its exit from the maceration battery, and before defecation, into another vessel, whose strainers serve to detain some of the ligneous matters held by the juice. With the same object, it is well not to reduce the root to too fine a pulp; but it is necessary to avoid extremes in either direction, as a too coarse pulp will not be completely exhausted, and will thus cause a loss of sugar. The process is only suitable for use where fuel is abundant and cheap, in consequence of the very large quantity of water added, amounting in all to 3–4 times the weight of the root. It is therefore more applicable to rich than to poor juice. The cost of erection is moderate. Thus, for a factory taking 50 tons daily, the outlay would be:—Rasping-machine, 180*l.*; macerating-battery complete, 600*l.*; press, 200*l.*; steam-engine, 8 H.P., 200*l.*; total, 1180*l.* The expenses attending the extraction of the juice would be:—6000 tons of beet at 19*s.*, 5700*l.*; transport and washing, 160*l.*; interest at 10 per cent., 180*l.*; repairs, strainers, brushes, &c., 120*l.*; wages of 24 workmen, 134*l.*; washing the cloths, &c., 14*l.*; fuel for the steam-engine, 105 tons of coal, 150*l.*; fuel to evaporate 35 per cent. of water, 420 tons coal, 605*l.*; total, 7063*l.* The yield is 89 per cent. of juice, or 5034 tons in the season. The cost price is therefore 31*s.* a ton.

L. Walkhoff's "mixed method" of extraction is illustrated in Fig. 1302. Its most essential part is the filter-press or swinging vat A, resting by the axles *b* on cast-iron supports *a*; it can be turned round on its axis, and thus completely emptied. One or both of the axles *b* are hollow, and furnished with a stuffing-box, so that water can circulate in the interior of the axles, whatever the position of the vessel. A tap *d* regulates the delivery of water from a reservoir *w*, which may be 10–30 ft. above the apparatus. The water admitted by the hollow axles *b* passes by the pipe *e* into a perforated worm, whence it escapes beneath the double false bottom *f*. Thus its level is raised slowly and uniformly. At *g*, is a cover pierced with holes, forming a diaphragm, provided with a handle, and resting in the interior of the vessel upon circular bearers, where it is held by screws. To prevent the water passing directly along the sides, the double false bottom is fixed to a T-iron rim riveted to the vessel. The large-bore tap *n* is for letting out the water rapidly when the juice is displaced. At the top of A, is a tap *m* for outflow of juice.

Once the vessels A are full, the metallic strainer *l* is placed on the pulp, and the cover *g* is adjusted. The tap *d* is then opened, so that the water occupies 12–20 minutes in filling the vessel A. The water enters at the bottom; as it rises, it displaces the juice in the pulp, mixing more or less with it. The liquid thus approaches the tap *m*, and escapes at about the normal density of the juice. The workman soon learns the correct adjustment of the tap *d* necessary to give the proper duration to the operation. The pulp, being lighter than the water, rises as a scum up to the strainer *l*, but is there retained, so that the liquid escapes quite clear. The usual length of operation required is 20 minutes. The diameter of the vessels A should not exceed about 28 in. With this size, the pulp of about 8 tons of beet can be worked in a day of 24 hours, or say 6 vessels for 50 tons per diem. This system has been very largely adopted in continental Europe, on account of its good working results. The appended table exhibits its capabilities in comparison with other modes:—

1302.



	Yield of Juice.	Yield of Pulp at uniform dryness.
	per cent.	per cent.
Ordinary presses	80	20
Simple presses, with 50 to 60 per cent. of water added in the rasper	84	16
Kuhne and Bökelmann's double pressing	87	13
Schlickeysen's process	88½	11½
Walkhoff's "mixed method"	92	8

More recently, Walkhoff has introduced modifications tending to reduce the labour. His principle is to reduce about 70–80 per cent. of the juice by a preliminary treatment, of the simplest possible character, for which many mechanical appliances already exist. The pulp coming from this treatment is thrown at *a* into the apparatus shown in Fig. 1303. Thence it passes under a great number of blades, which divide it into small fragments, and thus it reaches the large drum *b* in a uniform and continuous stream, there to be still further comminuted by the edges *c*, and delivered to the juice-extractor. This latter, called a "revolving filter," is provided with paddles, and resembles a water-wheel. This revolves slowly, and causes the pulp to circulate in opposition to a current of water entering at *e*. The completely exhausted pulp is discharged at *g*, and falls into the gutter *h*, whence it is conveyed to store. The whole apparatus rests by its axis *n* on a support *m*, and is actuated by the wheels and pulley shown. The tap *o* serves as an outlet for the water from the apparatus. The water, entering in the desired quantity at *e*, passes successively into each compartment, and escapes at *f* as concentrated juice. The apparatus is very simple, and effects the complete extraction of the sugar, without adding more than 5 per cent. of water on the weight of beetroot.

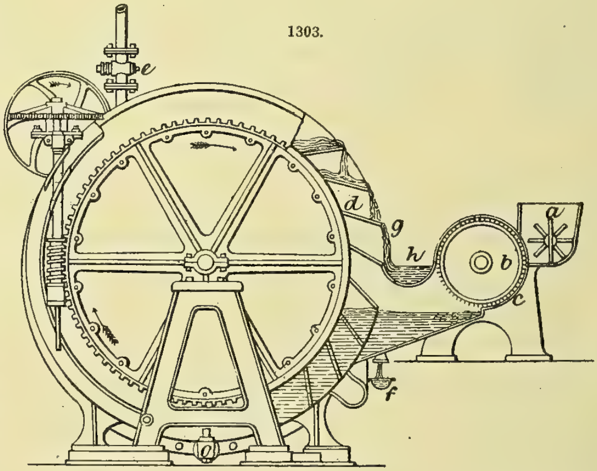
Many other plans, depending more or less upon maceration, have been proposed, such as Pelletan's, Reichenbach's, Hallette et Boucherie's, Martin et Champonnois', Schiskoff's, Robert's, Schutzenbach's, &c., but they do not possess any valuable feature entitling them to notice. The preceding systems are those most generally and successfully applied. A comparison of the results of the foregoing processes, in tabular form, is given on the authority of Walkhoff: for 120 days' work and 6000 tons of beet, the production of juice requires:—

Processes.	In Labour:			In Fuel:		Cost of First Establishment.	Annual Expenses for Repairs.	Percentage of Juice obtained.	Cost of Production per Ton of Juice at the Initial Density.		Percentage of Water added to the Juice.
	For Collecting and Cleaning the Beet.	From the Rasping to the Defecation.		For the Engines.	For Evaporating the added Water.						
		Per Shift.	Total No. of Days.	In tons of English Coal.							
						£	£		s.	d.	
Simple expression	3360	28	6720*	118·8	..	1340	288	80	28	0	..
Expression with second rasping of the pulp ..	3360	35	8400*	145·2	240	1540	300	87	27	9	20
Expression with the charging-tables adopted at Smela in 1862 ..	3360	14	3360*	118·8	..	1200	288	80	27	6	..
Centrifugals	3360	10	2400	237·6	360	1450	120	88	27	0	30
Schutzenbach's maceration	3360	12	2880	105·6	420	1140	120	89	31	0	35
Walkhoff's method ..	3360	20	4800*	130·2	125	540†	272	89‡	36	0	8–12

* Not including the washing of the sacks. † Plus the presses.
‡ This method gives up to 94 per cent. of juice, and the figure stated is the absolute minimum.

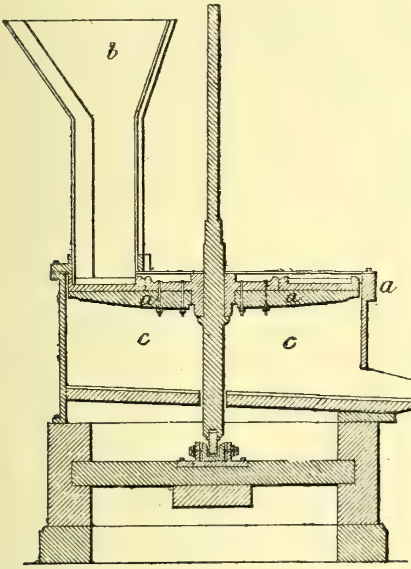
Diffusion.—The processes hitherto described for extracting the juice from the beet have depended for success upon the more or less complete rupture of the cells containing the juice. "Diffusion" differs from them essentially, in dispensing with the breaking-up of the cells. The constituents of beet-juice may be classed under two distinct groups: (*a*) "crystalloid," including the sugar and other "salts" capable of assuming a crystalline form; (*b*) "colloid" (glue-like), embracing the gummy or mucilaginous matters not capable of crystallization. The two classes are distinguished by a physical fact which forms the basis of all modifications of the diffusion system,—the difference which they manifest with regard to the power of passing through moist water-tight membranes. Bodies belonging to series (*a*), dissolved in water, pass through most animal and vegetable membranes (gut, parchment, plant-cells, parchment-paper), when there is water on the other side; those of series (*b*) are not possessed of that property. This method of separation is termed "dialysis," "osmosis," or "diffusion," and the membrane is called a "septum" or "dialyzer." The dead cell-walls of the plant itself form an excellent dialyzer; therefore, by cutting the root into convenient slices, and soaking these in water, the crystalloids (including the sugar) pass through the cells into the surrounding water, while the colloids mostly remain in the cells. Thus the juice is at once more or less purified, and is at the same time less contaminated with vegetable débris resulting from the mechanical breaking-up of the root.

1303.

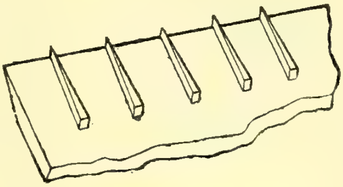


If slices of beet are placed in a vessel with about the same quantity of water, the following changes take place. The water forces its way through the cellular membranes into the sugar-cells, displacing a portion of the saccharine solution, which passes out, thereby diminishing the sp. gr. of the juice left in the cells, and increasing that of the water outside; this interchange continues till the liquid in the vessel has attained the same sp. gr. as that in the cells: the diffusion is then complete. Supposing the juice in the cells to be at sp. gr. 1·0435 (equal to 12 per cent. by saccharometer), and the surrounding water 1·0000, when the diffusion is complete, the water will be sp. gr. 1·0237 (equal to 6 per cent. by saccharometer), and the now diluted juice in the cells the same. Consequently complete exhaustion can only be accomplished by fractional diffusion, i. e. by substituting for the liquid obtained another of less sp. gr., and this replacing of the more saturated liquid by a less saturated one must be continued until the desired degree of exhaustion is reached.

1304.

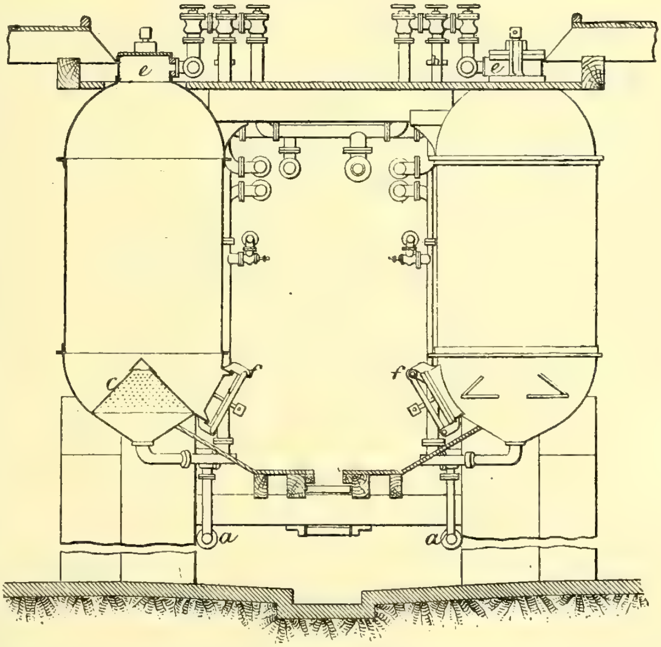


1305.

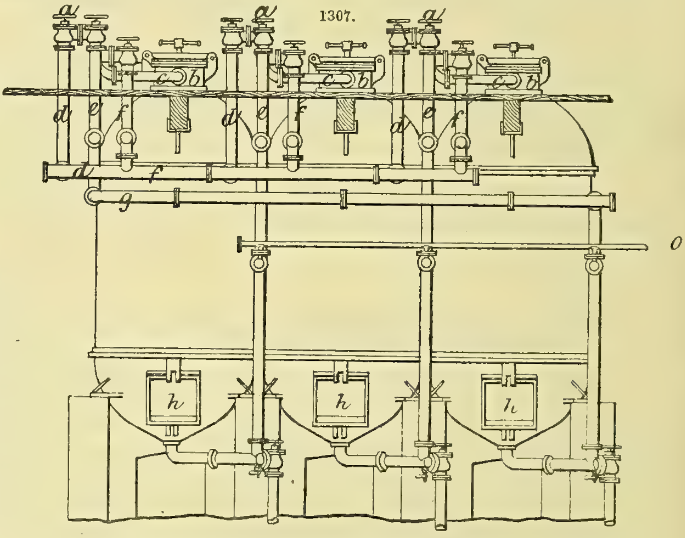


The first step in the process is to cut the roots into thin slices, great importance attaching to their thickness being uniform. The machine in common use, invented in 1850 for slicing beets for the hot maceration process, is shown in Fig. 1304. The cleaned roots fall into the hopper *b*, and encounter a plate *a* which turns horizontally, and carries 3 series of steel blades arranged at right angles. The roots are thus divided into rectangular prisms of varying length, without suffering any crushing or pressure. The slices fall into the space *c*, and escape at *d*. With 1½ H.P., this machine is said to slice 100 tons of beet per 24 hours. By using two feed-hoppers, the effect is doubled. For diffusion, the slices are about $\frac{4}{100}$ in. thick and $\frac{40}{100}$ in. wide. The cutting disc is furnished with knife-edges, as shown in Fig. 1305.

1306.



In Robert's diffusion process, the ribbon-like slices of beet are conducted to large closed vessels, mixed with the heated juice from a previous operation, and exhausted with cold water. The diluted juice is first heated to 75°–90° (167°–194° F.), so that the mixture assumes a mean temperature of 50° (122° F.), which is considered essential to success. Displacement of the juice is performed by a flow of cold water throughout the whole battery (of 5 to 8 vessels), arranged as in Figs. 1306 and 1307. The cylinders are furnished at top with manholes *e* for the introduction of the slices. Near the bottom, a hinged door *f* permits the exhausted slices to fall upon an endless web, which conveys them away. In the interior of the cylinder, is a case *c* pierced with holes, which prevents the pipes being obstructed by solid particles. The pipes *a e* put the vessels into communication with the reheating boilers, while the conduits *e g* and *c* maintain the circulation in the various cylinders of the battery. The steam-pipe *o* furnished with a clack serves for the introduction of steam to the several vessels. Pipes *d* bring the water necessary to the operation, while the rich liquor passes away by *f* to the defecating-boilers.

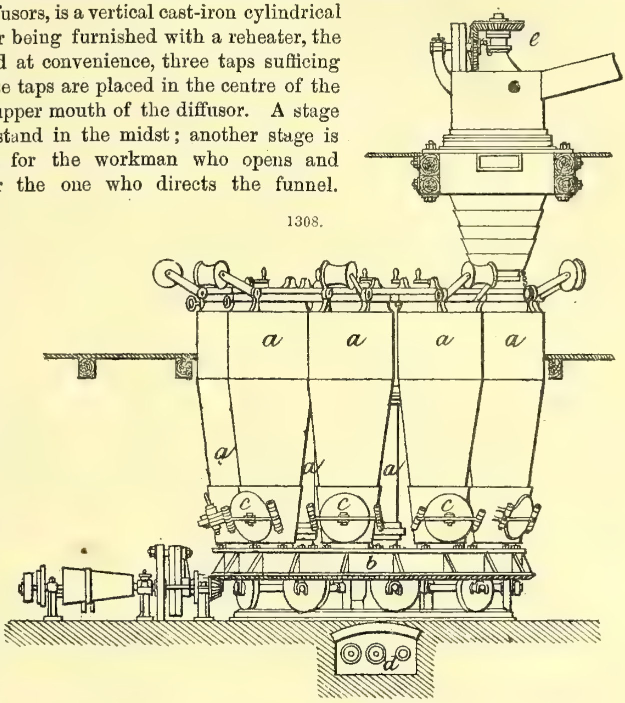

1307.

Each vessel receives 2½ tons of slices, occupying a space of about 132 cub. ft. The vessels are not filled until the juice or the diffusion-water, as the case may be, has a temperature of 87°–97° (189°–207° F.). The vessel is ⅓ filled with this hot liquid, and then the slices are fed in through *e* from trucks holding about ½ ton. On emptying the fourth truck, the reheated juice is allowed to run in at top, so that when the charging of the slices is completed, the vessel is full of juice. The proportions of juice and pulp entering the vessel should be carefully adjusted. Whilst charging, it is well to mix up the juice and pulp so that no part shall be left imperfectly exhausted, and the liquids shall have uniform circulation. As the contents of 6 or 7 trucks are needed to fill the vessel, and as the discharging of each occupies about 4 minutes, the whole charging requires nearly half an hour. The vessel once full, the cover *e* is closed, and the matters are left for about 20 minutes. At this moment, the pressure of the column of water from the tanks above the factory is brought to bear upon the nearly exhausted pulp in the last vessel. As this vessel communicates with the 7 others forming the battery, the pressure can be conveyed to them all; the juice is thus displaced from the cylinder filled with fresh pulp, and proceeds while still hot to the defecating-boilers. In practice, each vessel furnishes two full boilers of juice, varying in density according to the duration and the number of vessels (5, 7, and even 10). Generally, the density fluctuates between 4° and 7° B., so that the juice is mixed with about 40 per cent. of water on the weight of beet.

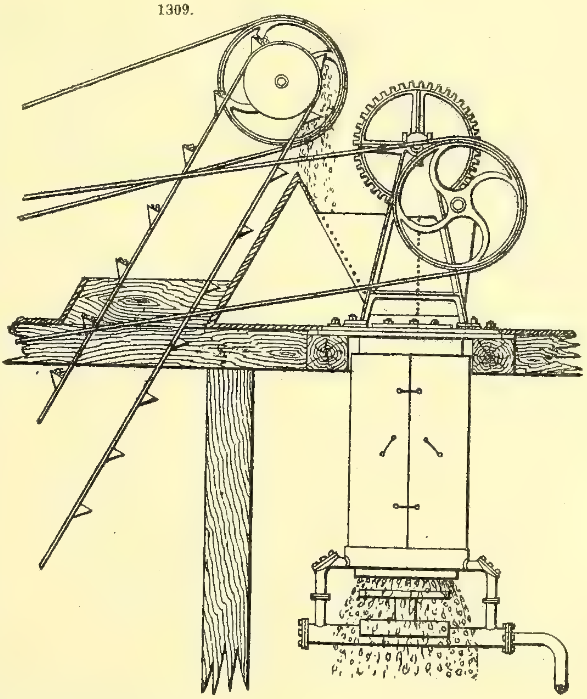
The estimated cost of establishing a factory on the diffusion system to work 50 tons a day, according to Walkhoff, is:—1 slicing-machine, 144*l.*; 10 cast-iron diffusors, weighing 1 ton each, 288*l.*; 50 cast-iron valves, 180*l.*; 20 traps, 52*l.*; 30 elbow-pipes, 13*l.*; 15 straight pipes, 22*l.*; 600 screws, &c., 14*l.*; 3 trucks, weighing 6 cwt., 50*l.*; total, 763*l.* The cost of extracting 100 parts of juice may be calculated thus:—6000 tons of beetroot, 5760*l.*; transport and cleaning, 161*l.*; interest and insurance at 10 per cent., 76*l.*; 15 workmen per shift, or 30 per diem, 173*l.*; removal of the residues (60 to 70 per cent. of the weight of beet), 4 workmen, 46*l.*; repairs, sharpening knives, &c., 58*l.*; residue-press, interest, repairs, &c., 50*l.*; fuel for 8-H.P. steam-engine, 88 tons of coal, 127*l.*; evaporation of 40 per cent. of water, requiring 480 tons of coal, 691*l.*; total, 7142*l.* The product is 90 per cent. of juice at the initial density, or, on 6000 tons of root, 5400 tons of juice. The juice, therefore, costs about 26*s.* 5½*d.* a ton; thus diffusion presents no advantage in this respect over the best systems of maceration.

A novel arrangement of diffusion apparatus, constructed by the Prager Maschinenbau Co., is shown in Fig. 1308. It is designed to take a maximum of 250 tons of beet per diem of 24 hours. This quantity is worked in Bohemia, where the juices are very dilute; if, instead of having juice at 3° B., it is desired to have it at 4° B., not more than 100 tons would be treated, at a sugar loss of 0·2 per cent. on the pulp. Four workmen suffice for the daily labour. In effect, the apparatus is rotary. The 9 diffusors *a* of which it is composed, having the form of inverted truncated cones, are borne in a circle on a wheeled table *b*. The motive power giving the rotation is ingeniously applied, and does not exceed 1 H.P. A complete turn is made in ¾ hour. The slicing-machine (*coupe-racines*) *e* is placed above on a special stage, and supplies the slices to each diffusor by means of an articulated funnel, formed of movable segments, so that its mouth can follow the slow rotary movements of the diffusor which it is filling, until the quantity suffices. The axis of rotation of the apparatus is composed of two concentric cast-iron conduits, one conveying the water, the other the steam. Between each two diffusors, is a vertical cast-iron cylindrical juice-reheater. Each diffusor being furnished with a reheater, the temperature can be regulated at convenience, three taps sufficing for each apparatus. All these taps are placed in the centre of the system, at the height of the upper mouth of the diffusor. A stage fixed here allows a man to stand in the midst; another stage is placed at the same height for the workman who opens and shuts the diffusors, and for the one who directs the funnel. The diffusors are closed at top by a heavy cover, resting upon a circular india-rubber tube, thus forming a hermetic joint, steam being admitted into the tube, so that it never flattens. The outlet of the diffusors is a lateral door *c* opening from above; a trough is provided for the reception of the exhausted slices. The juice is let out by taps *d* below the ground. A perforated sheet-iron plate forming a false bottom prevents the slices from mingling with the juice, when the tap is opened and the outlet-vessel is completely emptied of slices. A workman opens the lower doors each time a diffusor passes before the trough for the slices. A fourth workman is occupied at the slicing-machines. The advantages claimed for this system are as follows:—Easy charging of the diffusors, the slices passing direct from the slicing-machines, whence arises great economy of labour; the discharge of the exhausted slices takes place always at the same point; the duration of the diffusion, being regulated by the speed given to the apparatus, is always the same, and not at the discretion of the workmen; there is great saving in the construction, the pipe system being central and necessarily short.

1308.



1309.



Numerous other modifications are being from time to time introduced. For instance, compressed air is employed instead of water-pressure for effecting the final exit of the juice, so that the first diffusor, at the moment of emptying, contains only fairly dry slices.

The exhausted slices derived from the diffusors form a valuable cattle-food. But, as generally discharged, they are too wet for immediate use, and require to be passed through a press for the removal of the excess moisture. This is commonly performed in the Kluzemann press, shown in Fig. 1309. It is composed of a screw working in a conical space, which squeezes the pulp till it contains no more than the desirable quantity of water. The objection to this press is that it breaks up the slices. Skoda, of Pilsen, Bohemia, makes a continuous press, which avoids this disintegration of the exhausted slices. It consists of two eccentric cylinders placed one within the other, of different diameters, moving in the same direction and at the same peripheric speed. A screw causes the wet slices to fall into the interior of the larger cylinder, and they are carried by the general movement into the limited space between the outer surface of the small cylinder and the inner surface of the large one, and which is regulated by a double iron ring fixed on the inside of the large cylinder. This machine easily presses in the 24 hours the exhausted slices from 150–175 tons of beet, reduced to 40–45 per cent. of the original weight. The motive power required is about 1½–2 H.P. The price of the machine is about 280*l*.

Defecation of the Juice.—The average composition of freshly-extracted beet-juice is approximately as follows:—

In 100 parts of juice.

Sugar.	Diffusion.			Sugar.	Expression.		
	Potash, Soda, Silica, Lime, and Magnesia.	Organic Substances.	Weight of Solid Matters.		Potash, Soda, Silica, Lime, and Magnesia.	Organic Substances.	Weight of Solid Matters.
9·138	0·507	1·288	11·65	11·25	0·671	1·467	15·658
In 100 parts of dry substances.							
62·203	4·958	13·565	19·274	59·419	4·952	14·973	20·656

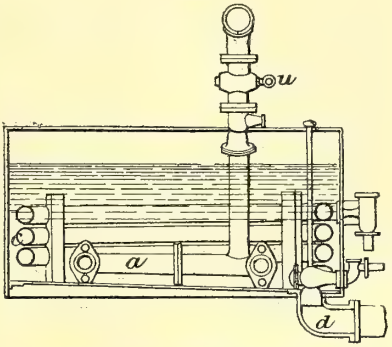
Defecation by Lime and Carbonic Acid.—This impure juice can be clarified to some extent by simple boiling, as the albuminous (nitrogenous) constituents coagulate in the same way as those of cane-juice, and form a supernatant scum; but the coagulation is very imperfect. The addition of slaked lime greatly facilitates the aggregation of impurities, by the formation of insoluble lime compounds; but a coincident effect is the prevention of the coagulation of the albuminous matters, which remain in solution till partially destroyed by boiling in the presence of the alkali. The part played by the lime is very complex, and not clearly made out, but it seems to displace many of the bases in combination with sulphuric, oxalic, and other acids, forming insoluble compounds with those acids, and further destroys some of the albuminous matters, as evidenced by the disengagement of ammonia when the temperature is raised. The convenience and cheapness of lime as a defecator are obvious. Its use underwent many modifications till 1849, when carbonic acid was proposed for neutralizing the excess of lime. In this direction, successive steps were made by Rousseau, Maumené, Périer et Possoz, Cail, Frey, and Jenileck, and the process, termed "double carbonation" (*double carbonatation*), has come into almost universal use.

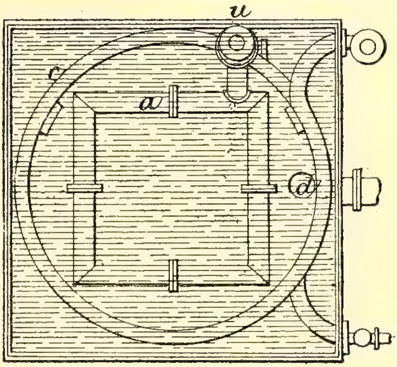
The method of carrying it into practice is as follows:—(1) Put lime into the juice as soon as possible, even into the mixture of juice and pulp, by introducing milk of lime into the rasper, or a weak solution of sucrate of lime, which, under proper conditions, does not appreciably alter the value of the pulp as a cattle-food. (2) Let the contact of lime and juice be sufficiently long, such as when preserving juice in cisterns, in the store-tanks at the exit from the rasping, or when transmitting it through the Linard pipe system (p. 1836); thus the free acids which would alter the sugar are saturated, and a very satisfactory cold defecation is obtained. (3) Introduce the turbid juices into the first-carbonation vessels, described further on, then adding $\frac{15}{1000}$ to $\frac{30}{1000}$ of lime in the state of milk of lime. (4) Pass carbonic acid gas in the cold up to about the middle of the carbonation; then gently admit steam to warm the juice; the supply of carbonic acid is stopped when the juice does not contain more than $\frac{2}{1000}$ of lime. (5) Turn the steam on full till the temperature reaches 90° (194° F.), to throw up the scum; allow to rest, and decant. (6) Transfer the clear juice to the second-carbonation boilers, add $\frac{2}{1000}$ to $\frac{10}{1000}$ of lime, and heat to boiling, in order to destroy the nitrogenous matters not eliminated by the first carbonation. (7) Pass carbonic acid till the lime is completely saturated. (8) Give a rapid boiling, allow to settle, and decant.

In the double carbonation process, the purification is effected in two ways. The carbonic acid, in uniting with the lime in the midst of the juice, forms carbonate of lime, which, on precipitating, carries with it a large quantity of organic matters. The scums of the first carbonation are thus very dark. The supply of carbonic acid is stopped when its further action would redissolve the colouring matters. In the second carbonation, the lime-boiling destroys the matters which resist the first carbonation. The excess of lime is finally removed by carbonic acid.

The apparatus and its manipulation may be described as follows. At the exit from the presses and the diffusors, the juice is received either directly into the carbonation-boilers, or into a tank communicating with a pump or *monte-jus*, for filling the carbonators placed at a higher level. The *monte-jus*, pumps, and defecating- and clarifying-boilers will be found described under the section on Cane-sugar. The carbonating-boilers are of various forms, composed essentially of large rectangular tanks (Figs. 1310, 1311), generally of greater depth than width. Around their circumference, passes a steam-worm *c* of large diameter, to rapidly heat the mass of liquor. At the bottom of the tank, runs a pipe *a*, which separates into two branches, or takes the form of the tank. This pipe is pierced beneath with small holes, whose total area is less than the section of the pipe; at the end, it rises in front of the boiler, and bears a tap *u* within the operator's reach. It then conducts to the carbonic acid source, and serves for introducing this gas into the liquor. The bottom of the boiler is inclined towards the front, and has in the lowest part a large plug *d*, or a tap for rapidly drawing off the liquid. Thermometers are attached for ascertaining the temperature. The boilers are the same for the first and second carbonation, except that the first produces a tenacious scum which must be beaten down. This is effected in two ways: either by furnishing the boilers with ledges, and a cover provided with a long chimney, when the scum stops at a small height in this pipe; or by placing at the top of the boiler, throughout its whole length, perpendicularly to the side where the workman stands, and on each side, two pipes of small diameter pierced laterally with little holes, through which steam is passed at high pressure. The escaping steam blows the scum back into the boiler. This latter apparatus, termed "Evrard's skimmer," works well, but requires much steam.

1310.





1311.

Below each carbonating-tank, is placed a decantation-vessel, generally of the same form and dimensions, into which the liquid flows when let out of the carbonators by the plug. These decantation-vessels, whose floor is also inclined and furnished with a plug, have in front an external tap, connected inwardly with a flexible tube provided with a float which maintains the mouth of the tube at the clear surface of the liquor. When the turbid carbonated juice has been run into these vessels, it is allowed to settle and clarify itself, and is then decanted. The clear juice is received in a conduit which conveys it to the second carbonation, or to the filtration. When the float reaches the deposit, the workman closes the tap, opens the plug, and lets out the semi-solid mass into a trough connected with the filter-presses (p. 1848). In some works, the decantation-vessels are dispensed with, the operations being conducted in the carbonator.

The lime and carbonic acid employed in the operations are usually made at the factory. With this object, a large continuous lime-kiln, Fig. 1312, is built near. The gases escaping from the calcination of the limestone contain 25–30 per cent. of carbonic acid gas; they are drawn away from the exit of the kiln by the suction of a large pump, whose speed is regulated according to the state of the kiln. This pump forces the gas into the general pipe serving all the carbonators, which pipe is furnished with a safety-valve. Between the kiln and the pump, the gas traverses a "washer," a vertical cylinder with perforated trays, entering at the bottom by a perforated pipe, and escaping at the top by the pipe *f*, while a stream of water, conveyed by the pipe *p*, falls in showers over the trays and comes into contact with the ascending gas. According to the richness of the gas, the kiln is regulated: it is thus necessary to make frequent tests of the gas. One of the most convenient instruments for this purpose is that of Wigner and Harland. The lime to be used in defecating is first slaked in special tanks furnished with agitators. It is then diluted with sufficient water, carefully strained, and constitutes a milk of lime having a density of 20°–25° B.

Treatment of the Lime Scums.—The scums collected in the lime defecation process contain, in the fresh state, sugar, numerous nitrogenous matters, and other fertilizing elements. Plicque, working upon scums having the composition :

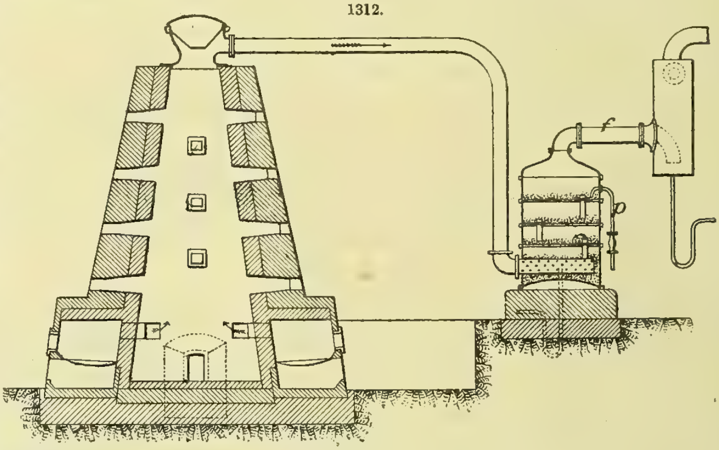
Water	52·70 per cent.	Organic matter	9·24 per cent.
Sugar	3·50 „	Phosphates	4·77 „
Nitrogenous matter	3·72 „	Lime, silica, iron, &c. ..	26·07 „

obtained the following products, estimated on the dry weight :—

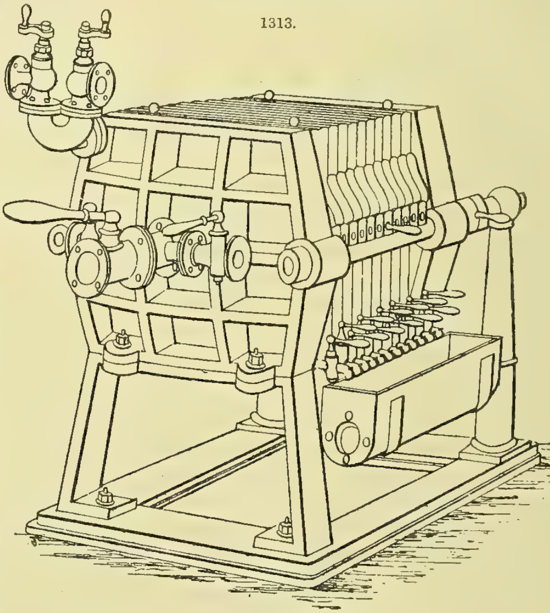
Animal black	50·0 per cent.	Alcohol at 85°	2·0 per cent.
Lime	35·5 „	Sulphate of ammonia	1·0–2·0 „

The excess of moisture is removed from the "green" scums by the use of filter-presses. The scums of the two carbonations are collected in the same cistern, fitted with two *monte-jus*. The escape-pipes from these *monte-jus* reunite into one, so that though the *monte-jus* are used alternately, there is no fluctuation in the supply of scum to the filter-presses. The systems most largely used are those of Trinks, and Durieux et Roettger.

1312.



1313.

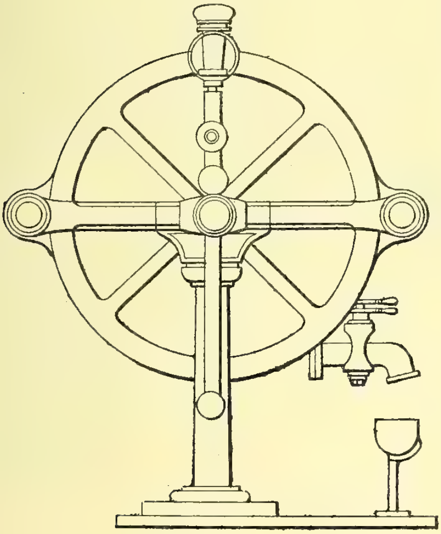


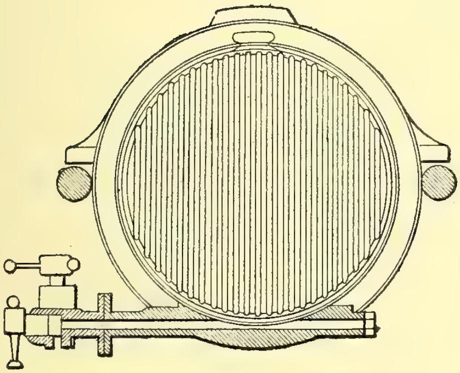
Trinks' press, Fig. 1313, is composed of a series of cloth bags, held against metallic plates pierced with holes. The *monte-jus* forces the dirty liquid into these bags; the juice runs away clear, while each bag fills with the solid scum, which is strongly compressed by the steam in the *monte-jus*. When the bags are full, the juice no longer escapes; then, to remove the superfluous moisture from the scum, steam alone is forced in. The steam condenses and washes the scum, dissolving the last traces of sugar, and yielding a slightly saccharine liquor. The action of the steam is continued until, having forced a passage, it escapes at the lower part of the apparatus. Steam is then shut off, and the operation is concluded. To enable the bags to be opened easily, they are formed of two quadrangular cloths put together, the four borders of which are pinched, two and two, between wrought- or cast-iron frames, presenting an opening only for the passage of the scum and steam. The frame, and consequently the set of cloths forming bags, are separated by metallic plates, which permit the juices to escape; these juices run along the plates, and collect in a gutter closed by a tap, with screws to regulate the speed of the outlet, and even to suspend the working of a cloth, when it is torn for instance, without stopping the whole press.

Farinaux's press is composed of plates analogous to those of Trinks. In the upper part of the frames are two bearers, on which is screwed a wrought-iron stirrup. A horizontal traverse is fastened to one side of the fixed frame, and passes through all the stirrups, supporting the frames. The advantages claimed for it are that it is easy to adjust all the frames to the same height, and that the dismounting and replacing of the frames is much easier. According to another plan of Farinaux's, the working of the press is rendered largely mechanical, so that one labourer out of two is dispensed with. The bags are made of sail-cloth, and last 24–30 days, while those of jute endure only 5–8 days.

Durieux et Roettger's press is shown in Figs. 1314 and 1315. Numerous other forms might be specified, but their effect is practically the same.

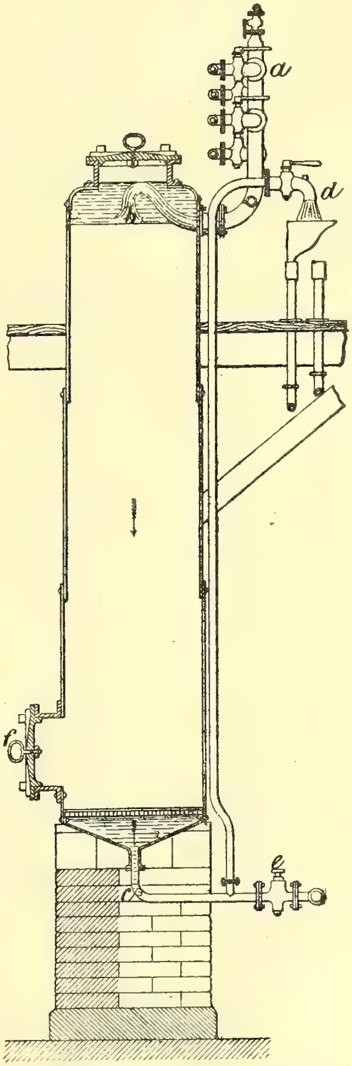
1314.





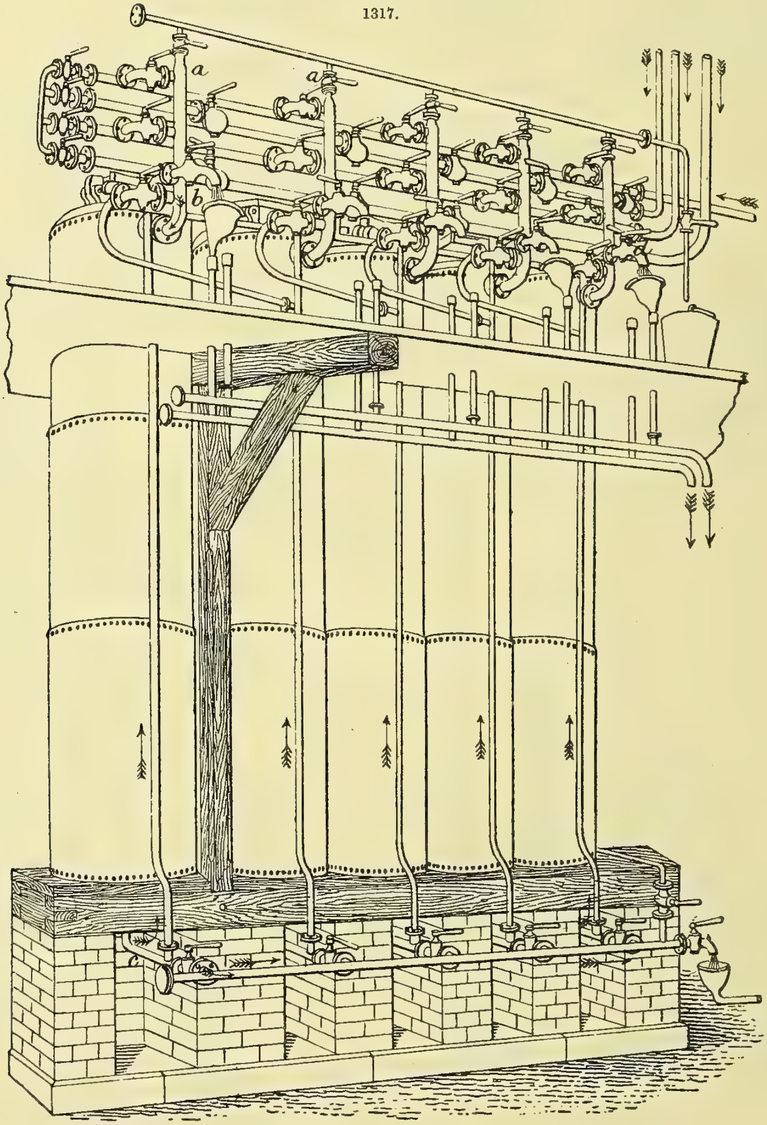
1315.

1316.



Ammonium phosphate Process.—A process was invented some years ago by Lagrange, chemist at the refinery of Guions, Paris, for separating the calcium and magnesium salts, with which beet-sugar is especially liable to be contaminated (see analyses p. 1846). The object of the process is to throw down the calcium and magnesium as tribasic phosphates, by the addition of tribasic ammonium phosphate, $(NH_4)\,3PO_4$, to the syrup. Much, sometimes nearly the whole, of these earthy salts, exists as sulphates, though portions are usually chlorides or nitrates. The salts of the earthy bases retard the crystallization of the sugar, with varying effect according to the particular metals they may contain;—and the acids, especially if they be mineral acids, with which the earthy metals are in combination, likewise possess specific powers of their own in retarding the crystallization of more or less sugar. Sulphuric acid would appear to be the most powerful, while phosphoric acid seems to exert little if any influence; small quantities of ammonium phosphate are indeed stated to rather favour crystallization. Lagrange's process simply and ingeniously contrives to get rid of the calcium and magnesium, and, by the same operation, to precipitate and extract any sulphuric acid present.

1317.

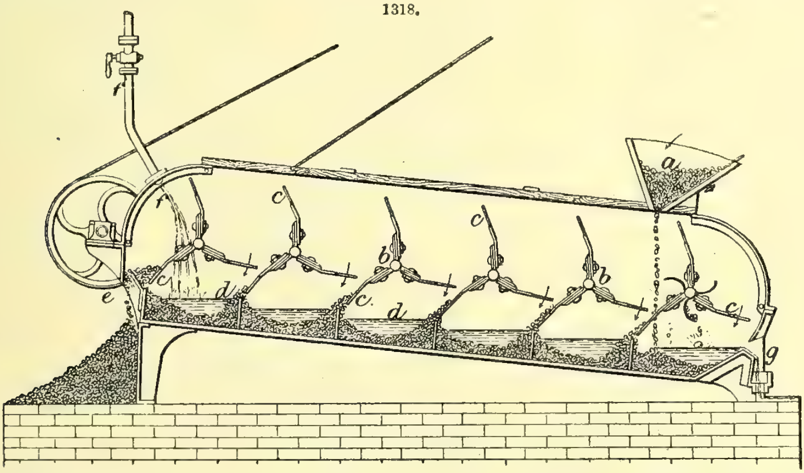


A quantity of syrup having been made, the amount of sulphuric acid and earthy salts present is ascertained, the latter by means of the soap test (see Analysis). It is now heated to boiling, and a solution of barium hydrate in hot water is added in trifling excess beyond what is required to combine with and throw down all the sulphuric acid; this is immediately followed by an addition of ammonium triphosphate, equivalent to or slightly in excess of the total earthy metals. These will consist of any excess of barium hydrate that may have been added, together with any calcium or magnesium originally present. A mixture of barium sulphate, barium triphosphate, and calcium and magnesium triphosphates, goes down, sweeping with it from the syrup much of the glutinous and colouring matters. The syrup is next passed through a Taylor filter, to separate the precipitate; if the operation has been properly conducted, the syrup should contain some free ammonia, and just a trifling excess of the ammonium triphosphate, but no earthy bases nor sulphuric acid. The syrup is now fit to be boiled and crystallized.

For some time after this process had been devised by Lagrange, it was impossible to procure ammonium triphosphate at reasonable prices, the only mode of manufacture being the production (1) of neutral ammonium phosphate, by saturating pure syrupy phosphoric acid with ammonia, so as to form a highly saturated solution of the salt, and (2) then adding one more equivalent of ammonia, so as to throw down ammonium triphosphate, which latter salt is only soluble in weak aqueous ammonia to the extent of about 6 per cent. F. Maxwell-Lyte, however, introduced a method of producing pure ammonium triphosphate from the acid calcium phosphate afforded by natural phosphates, which at once reduced the price of ammonium triphosphate from 2*s.* 6*d.* to 8*d.* a lb., and thus placed the salt within easy reach of the sugar-makers. Guions, who employed the process in their refinery, state that, besides affording an additional 5–10 per cent. of crystallized sugar, they are enabled to work with far less animal-black (char). The process is equally adapted to the defecation of raw beet-syrups, and was thus worked for some time by Daniel, near Compiègne.

Filtration through Animal-black.—The defecated and carbonated juice has in a great measure lost its alkaline character, having been deprived of the greater part of the dissolved lime by means of the carbonic acid. There is, however, still some lime to be removed, as well as a considerable quantity of gummy and albuminous substances. These, and the colouring matter which gives a brown tint to the juice, are in a large degree eliminated by passing the juice through animal-black (char, animal charcoal). This is done by taking the juice from the carbonating-pan into an iron cistern, and there heating it nearly to the boiling-point, afterwards passing it through vessels filled with granulated animal charcoal. The juice finds its way through this gradually to the bottom; and runs out while a fresh supply is poured in at the top. The charcoal has a considerable power of absorbing bodies such as dextrine, and with long time and hot liquor, the action is intensified, and the purification is materially great. This juice to be sent through the charcoal filters is a turbid sticky mass; it is elevated either by a pump or a *monte-jus* into a cistern situated above the series of filters. After the filtration, the juice is in the condition known as "thin"; it is nearly colourless, and is largely freed from lime, and from gummy and albuminous bodies which escaped the action of the lime. In this state, it passes to the concentrating system.

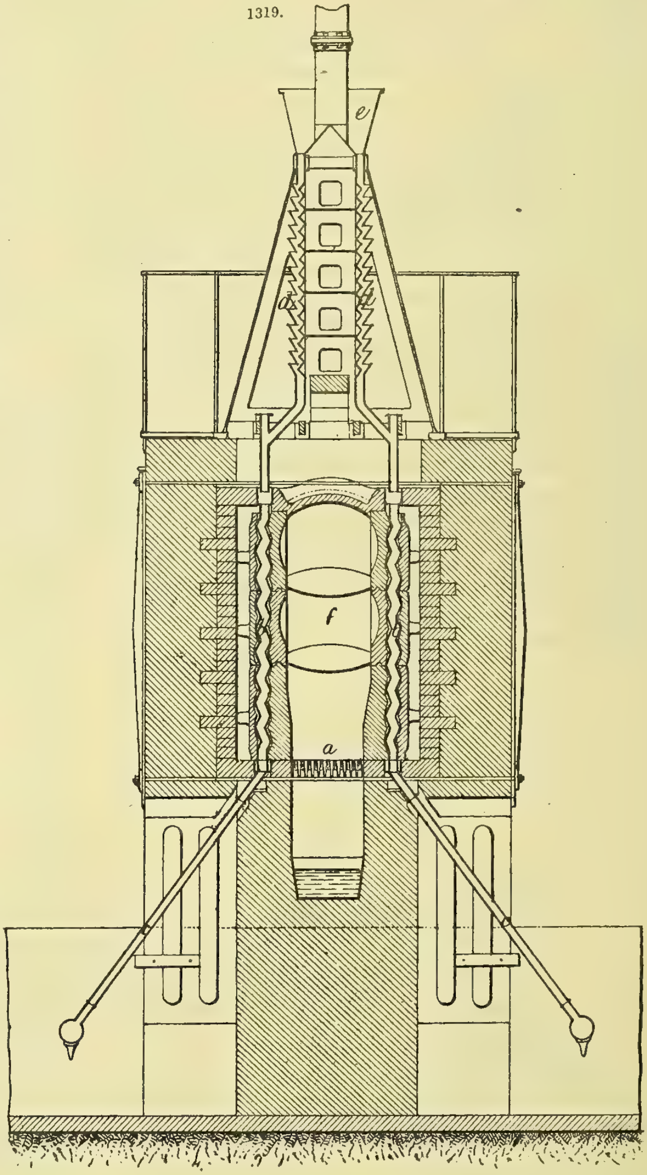
1318.



The filters used are of two kinds. The older sort, known as "Dumont filters," consist of cast-iron cylinders, 6–12 ft. high, and 3 ft. or more diam., open at top, furnished with a false bottom covered with cloth, as well as a man-hole at the level of the false bottom. The cylinder is filled with black, and the juice is run in at top at such a speed that the black remains always covered with a thin layer of liquid. A pipe, leading from the bottom, curves up, in the form of a swan-neck, to half-way up the cylinder.

The other kind, termed "closed filters," are shown in section in Fig. 1316, and as a battery in Fig. 1317. They are 32 in. diam. and 12–16 ft. high; the juice enters by the pipe *a b*, coming from a cistern placed at a higher level, and escapes by a pipe *c* leaving the bottom, and bent up to the summit *d* of the cylinder. This modification possesses the advantage of effecting the filtration out of reach of air and chills, and enables several filters to be in communication, so as to multiply the height of charcoal through which the juice passes. When a filter is judged to be no longer effective, as seen by the questionable colour of the liquor, the supply of juice is stopped and replaced by boiling water, and when the water has driven out the saccharine fluid, the tap *e* is opened at the bottom, the liquor is run out, the black is withdrawn at the man-hole *f*, and the filter is washed, and recharged with new black over which a current of boiling water is passed. The filter is then ready for use again.

1319.



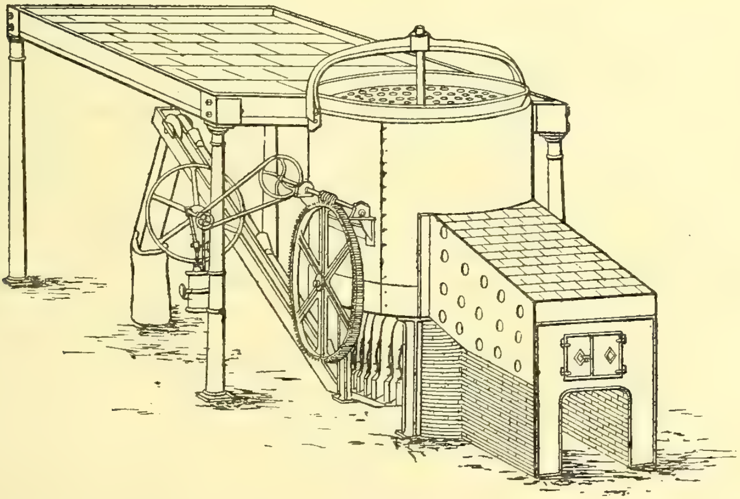
Washing the Charcoal. — The animal charcoal used in these filters is rarely prepared in the sugar-factory itself; but usually it there undergoes a washing operation, as well as a process termed "revivification." The washing is as follows. After having been subjected to fermentation, or to a treatment with alkali at 100° (212° F.), the black is washed with water till it ceases to communicate the least turbidity. Numerous machines have been introduced for carrying out these conditions, the main objects being to cleanse thoroughly, employ a minimum of labour, and avoid disintegration of the black. A typical form is Kluzemann's, Fig. 1318. It consists of a chamber divided by low partitions into compartments *d*, in which slowly revolve arms *c* mounted on shafts *b*, and terminating in flexible iron blades. The black falls from the hopper *a* into the lowest part of the machine; it is successively passed from one compartment to the next by the revolving arms, each time attaining a higher level, finally reaching the upper end *e*, whence it is ejected completely washed. The water admitted by the pipe *f* passes in a contrary direction through the black, and runs out at *g*. The machine is cheap and efficient, and washes about 15 tons per 24 hours.

Schreiber, of St. Quentin, has introduced a novel form of washer, in which the black is placed in contact with a stream of water by means of its own sp. gr., without the intervention of any mechanical appliance to cause its disintegration. The machine consists of a horizontal air-tight cylinder, 6 ft. long, and 28 in. diam., turning in external supports by means of toothed wheels engaging in toothed rings on the cylinder; in the interior of the cylinder, are two paddles or curves, and it is prolonged by a cylindrical part of less diameter. The pipe conveying water enters the cylinder at the axis of this smaller part. The black enters at the other end. In the centre of the cylinder, revolves an endless screw, which catches up the black; and an annular space is left throughout the cylinder for the passage of the water. During the rotation of the cylinder, the black is continually lifted by the paddles by the simple act of rotation, and at the same time a certain quantity of water is taken up, and falls back into the same bath with the black. In this movement, the grains of black traverse the water, and the washing is effected without shock or injury. The paddles are so inclined, that the black entering at one end is propelled along one side to the other end, returning in the same manner along the other side, and escaping finally at the end where it entered. The machine is spoken of in the highest terms.

Revivification.—By "revivification" of the charcoal, is meant the separation from it of those saccharine and other matters which it absorbs in the filtering process, thus rendering it fit for re-use. With this object, it is fermented to destroy the organic matters; washed with acid, with hot water, with cold water, and with steam; dried; and finally calcined in furnaces of very various construction. These all consist essentially of a system of cast-iron or earthenware pipes, heated to dull-redness, and closed at bottom by a method permitting the black to be withdrawn without admitting air, which would immediately cause the combustion of the red-hot carbon. This last condition is the one difficulty, and each maker strives to overcome it in a particular way.

Schreiber's kiln, shown in section in Fig. 1319, consists of a drier, vertical undulating pipes for the calcination, and inclined cooling-tubes terminating in boxes for regulating the discharge of the tubes. It is surrounded with masonry. On each side of the fire *a*, are placed the rows of cast-iron undulating pipes *b*, each composed of three pieces, fitting one within another. They are prolonged downwards by flat cast-iron tubes *c*, serving to cool the black, and forming an angle of 45° with the vertical pipes *b*. At the top, are similar undulating pipes *d*, with lateral openings forming venetian blinds in front, and crowned by a hopper *e* for holding the supply of black for the kiln. This forms the automatic drier. The undulating pipes *b* serving for the revivification are plated inside and out with slabs of fire-brick; these protect the iron from the fire, and regulate the transmission of heat, preventing the temperature exceeding 375°–450° (707°–842° F.), beyond which the black might be vitrified. The black is collected in the hopper *e* above; thence it descends into the driers *d*, enters the revivifiers *b* at about 90° (194° F.), and, when the operation is complete, escapes by the refrigerating-tubes *c*. A fire of coke or other fuel being lit in the furnace *a*, the flame spreads throughout the whole space of the fire-chamber *f* included between the two series of fire-slab coated tubes *b* and an arch at top, passes downwards, divides into two chambers right and left, heats the backs of the tubes, and again rises into a single flue passing through the drier *d*. The kiln is easy to build and manage, and turns out a black of superior quality.

1320.



The Ruelle kiln, Fig. 1320, has several advantages, and differs from most others in its general arrangement. It consists as usual of a series of cast-iron revivifying- and cooling-tubes. The whole of these are arranged in a bunch centred around a vertical axis, and suffer a slow, circular automatic movement of 2 rev. per hour, within a cylindrical furnace flanked by a lateral fire. The black is fed in a thin stream at the upper part of the kiln, and traverses the tubes, which are in turn presented to the fire, so that they are successively brought to a dull-red heat, thus ensuring regularity in the roasting, and avoiding those excesses of temperature which are always to be feared with fixed tubes. The rotary movement enables the discharge to be made automatically; each time a pipe reaches a certain point it meets a cam, which opens the outlet. A little elevator carries away the black as fast as discharged. The waste heat from the furnace circulates beneath a platform for performing the preliminary desiccation. This form of kiln is much used.

The Blaize kiln possesses a most interesting feature in the novel method of manipulating the revivifying-pipes with regard to the escape of the gases and watery vapour during the heating. The black, after washing and vaporizing, still retains some internal humidity, which can only be driven off by calcination. If the kiln is charged with too-wet black, this forms a plug at the top of the tube, preventing the escape of the vapour, which is then forced throughout the column of red-hot black; the latter is thereby decomposed, the carbon is calcined, and the combustible gases escape at the first opening which presents itself, usually between the joints of the pipes, dislodging them, to the deterioration of the kiln, the formation of white char, and the general interruption of the process. Ordinarily these evils are avoided by drying the black as strongly as possible before putting it into the tubes; the moisture then remaining can force a passage between the grains. In the Blaize kiln, the liberation of the vapours is facilitated in the following manner. The heads of the tubes are furnished with a transverse iron bar, composed of two sections, united by a simple covering of sheet iron, and supporting in the axis of the tube another pipe of smaller diameter, made of wrought iron, pierced with slots throughout its whole length, and which, penetrating the mass of black to its hottest part, favours the ready escape of the vapours, and conducts them to the chimney. The black reaches the tubes in a dry state, as it previously passes through the drier,—a chamber traversed by a large number of metallic tubes, through which travel all the combustion-gases, and which can be cleaned by opening the end; there is a trap for discharging the drier. The black has to undergo many changes of position before reaching the floor, thus ensuring its complete desiccation.

The second important feature in the Blaize kiln, is the construction of the tubes, which are of enamelled fireware. Cast-iron tubes wear out rapidly, and unenamelled fireware tubes produce white char, by reason of their great porosity, which allows air to pass. The enamelled tubes do not suffer from the heat of the kiln, as the enamel is put on at a white-red heat, such as is never attained in the black-kiln. Broken tubes can be readily mended by a special composition, and thus rendered as good as new. Moreover earthenware tubes afford a much superior black to iron ones. The construction of the kiln is very simple, and obviates the use of arches, which never withstand fire well. The upper bed and the second floor are formed of square blocks of fireware, through the centre of which pass the tubes. The tubes support the blocks, so that the expansion is uniform, and does not damage the kiln. Broken tubes or blocks can be removed and replaced without pulling the kiln about. The second floor rests upon the cooling-tubes, which are of cast iron, and furnished at bottom with traps and drawers, facilitating the discharge of a set every 20 minutes.

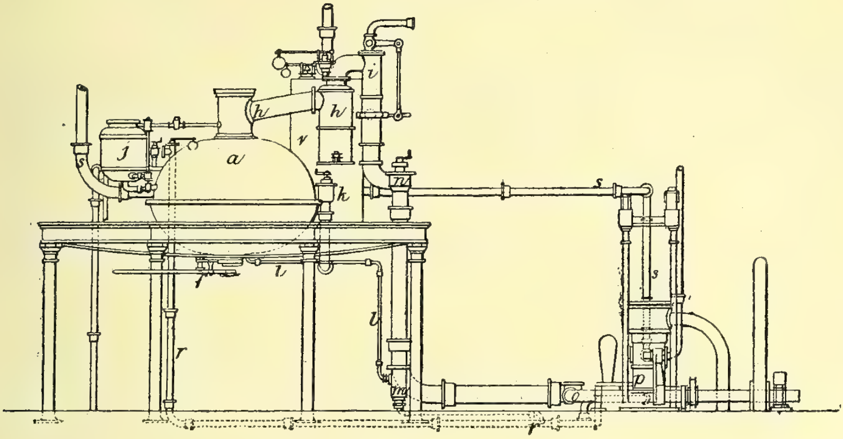
Other forms of revivifying-kiln are described under Refining.

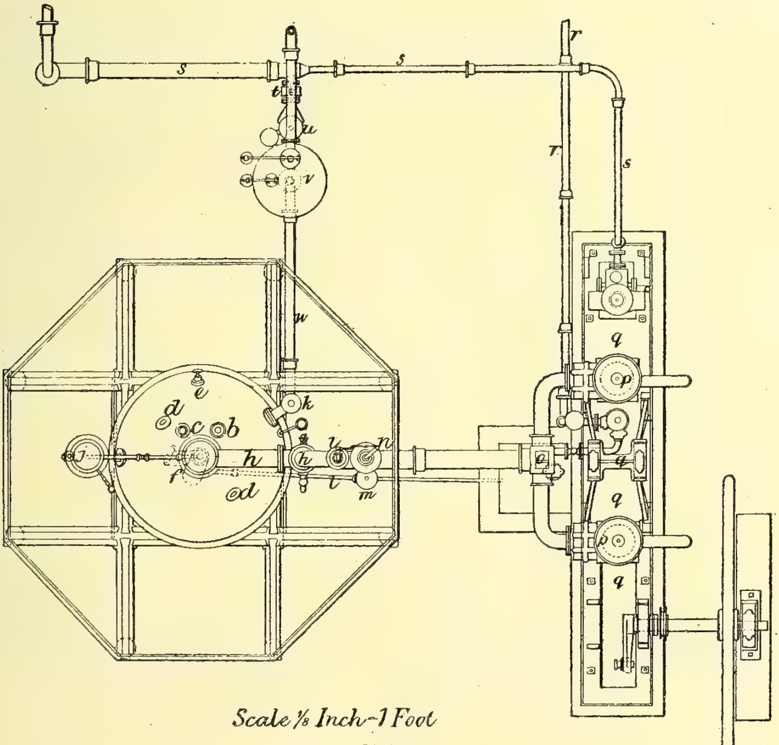
Concentration of the Syrup.—The next operation is the concentration of the "thin" juice, the removal from it of the excess of water, so that the liquid may become sufficiently dense, or saturated with sugar, to enable the latter to crystallize out.

Principles.—While the primary object of concentration is to get rid of useless water and form a solid material, the purification of that material by mere crystallization must not be overlooked. By this act, the particles leave in solution those bodies which are present in too small proportion to admit of their crystallizing out, as well as those incapable of crystallizing. The crystals, freed from their mother-liquor, are considerably purer than the original solution from which they have formed. Crystallization is the property which many bodies (including true sugar) possess of assuming a definite solid form out of a saturated solution when cooled: it is based upon the power of water to hold these bodies in solution in a degree varying with the temperature, this power (in most instances) increasing with the temperature. Thus if a gallon of hot water is made to dissolve as much sugar as it is capable of holding in solution at the temperature exhibited, and this "saturated solution" is cooled, the decreasing solvent power of the water compels the sugar to separate from it in crystals. These crystals are a combination of sugar and water: but the water is chemically combined, and cannot be driven off without decomposing the sugar; consequently this "water of crystallization" is regarded as an integral part of the substance, and the crystals are looked upon as pure bodies. Their size depends partly upon the conditions under which they are formed, these conditions being chiefly the duration of the operation, the bulk of water present, and the agitation or quiescence of the liquor.

In concentrating sugar-liquor to a saturated solution, it is necessary to bear in mind the changes which sugar suffers when subjected to heat. First it melts; then, if the heating be continued slowly and regularly, it parts with successive molecules of water, becoming converted into a number of uncrystallizable non-saccharine bodies, and ultimately into "caramel," a dark-brown substance used for colouring porter and other liquids (see pp. 598–9). This conversion takes place in concentrated solutions, as well as in the dry state. As evaporation proceeds, the mass thickens, and the difficulty of equalizing its temperature increases, with consequent liability of certain portions becoming transformed into caramel. Another change which is constantly proceeding in the liquor is the inversion of crystallizable sugar into uncrystallizable. This is caused by pre-existing uncrystallizable sugar, acids, and mineral salts, and is favoured by exposure to air and heat. The consequence of these changes is "molasses,"—an artificial product, composed of uncrystallizable sugars, and coloured by caramel. The value of molasses being far below that of

1321.





1322.

sugar, the prevention of its formation is one of the chief aims of modern improvements in sugar-making plant.

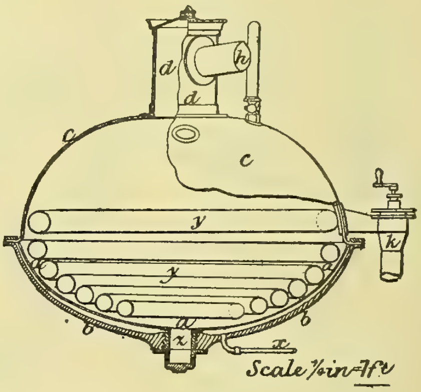
The difficulty of boiling dense liquids is well known. The cause of this difficulty is the lessened ability of the vapourized water to overcome the pressure of the atmosphere, normally amounting to about 15 lb. a sq. in. By relieving the liquid of this pressure, the "boiling" (i.e. the driving-off the watery vapour) can be effected at far lower temperatures, reducing the consumption of fuel, and lessening the danger of burning the liquor. To apply these principles to the concentration of sugar-syrups, the various forms of vacuum-pan have been introduced, in all of which the boiling proceeds *in vacuo*.

The first step with beet-syrup is to boil the watery liquor in a "double-effect" or "triple-effect" apparatus till it marks 25° B., then known as "thick juice." It next goes to a cistern where it is heated to boiling, and is again filtered through animal charcoal, by which more colouring matter is removed, as well as some albuminous bodies that are more readily absorbed from dense than thin liquors. After this second filtration, the juice is brilliant, transparent, and almost colourless, but still contains much water. This is finally removed by boiling *in vacuo*.

In the matter of concentration, the treatment of beet-sugar and cane-sugar are precisely similar; but there are a few variations in the apparatus, the forms employed in the cane-sugar industry being largely of English manufacture, while those used in beet-sugar factories are essentially Continental.

The vacuum-pan and its accessories are shown in elevation and plan in Figs. 1321 and 1322. The pan *a* is mounted on a cast-iron framing, carried by 8 cast-iron columns. Boarding or iron plates form a staging round the pan. The pan is fitted with thermometer *b*, vacuum-gauge *c*, sight-glasses *d*, proof-stick *e* for extracting samples of sugar, slide *f* for discharging sugar, cock *g* to admit steam to clean out the pan, and arm-pipe and receiver *h* to catch any sugar that may boil over. The receiver is fitted with delivery-cock and air-cock for destroying the vacuum when necessary. The condenser *i* is fitted with a perforated pipe and stop-cock, a lever, and an index-plate, to regulate the supply of water for condensing the vapour from the pan; *j* is the measure for regulating the supply of syrup, fitted with stop-cock and inlet-pipe from the filtered-juice tank, a glass gauge to indicate the quantity of syrup, an outlet-pipe with stop-cock opening into the pan, and an air-pipe having a cock communicating with the pan for forming a vacuum in the measure. *k* is a valve for the supply of steam from the expansion-vessel to the worm of the pan; *l*, a pipe for carrying off condensed water from the steam-coil of the pan to the condense-box *m*, which communicates by a pipe with a brick tank from which the feed-water is supplied to the boiler; *n*, air-valve mounted on the air-main, for regulating the communication between the air-pump and the pan; *o*, dividing-box for distributing the flow of air from the pan to the air-pumps; *p*, two 16-in. air-pumps, 1 ft. 9 in. stroke; *q*, 10-H.P. high-pressure beam-engine fitted on diagonal frames, with 11-in. cylinder, 3 ft. 6 in. stroke, and 12-ft. diam. fly-wheel with 6-in. elliptic rim, 4-in. plunger feed-pump, stop-cock, clack-box, copper air-vessel, and feed-water supply-pipe *r* to a Cornish boiler; *s*, pipes for supply of steam to the engine and pan through the expansion-vessel; *t*, sluice-cock for regulating the supply of steam to the mercurial regulating-valve *u*, by which the supply of steam is regulated to the expansion-vessel *v*, fitted with a whistle-valve and safety-valve, to prevent excess of pressure in the worm of the pan; the steam passes from the expansion-vessel through the pipe *w* to the steam-valve *k*, which regulates its admisssion to the pan.

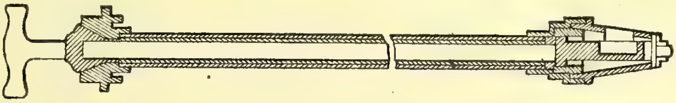
1323.



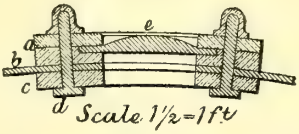
The pan is shown in section in Fig. 1323. The copper pan *a* is fitted in a cast-iron steam-case *b*, with steam-space left between, and is surmounted by a copper dome *c*. The copper and iron pans and the dome are bolted together through their flanges with a wrought-iron ring and bolts so as to be air- and steam-tight throughout. A man-hole *d*, with a ground gun-metal cover, is attached to the top of the dome, from which proceeds the arm-pipe opening into the receiver *h*. A steam-valve *k* opens into the copper steam-worm *y*. This worm gradually diminishes in diameter from the entrance-point at the steam-valve to the exit at the bottom of the pan. A wrought-iron pipe *x* is fitted into the cast-iron pan *b*, to carry off the water from the steam-case; the slide-valve *z* at the bottom of the pan is for discharging the sugar. The dome of the pan is mounted with a vacuum-gauge, thermometer, "sight-glass," and "proof-stick" for testing the concentration of the liquor.

The proof-stick (Fig. 1324) is simply a brass or gun-metal tube, which is driven from the upper part of the side of the vacuum-pan down an aperture made of the same size as the rod. When it reaches the bottom, the tube is twisted half round by the cross-handle, and opens a communication between the end of the tube and the syrup. In the end of the tube is a groove, into which the syrup enters; the handle is half-turned again, the tube is drawn out, and the entrance is closed as before. The liquor can thus be examined without destroying the vacuum in the pan. The sight-glass is shown in Fig. 1325: *a*, gun-metal rings; *b*, vacuum-pan; *c*, leaden ring; *d*, ⅝-in. bolt; *e*, glass plate. Figs. 1326, 1327 show a side-view and plan underneath of a slide. It consists of a gun-metal cup and slide *a*, and wrought-iron lever-bar *b*, fitted with bearings, and of the form and dimensions shown.

1324.



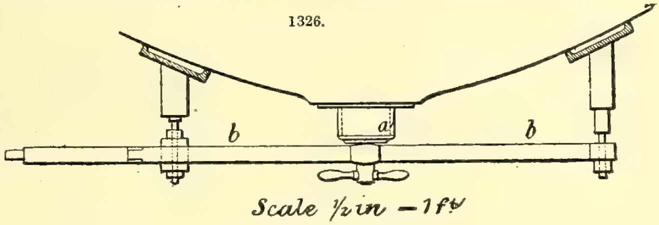
1325.

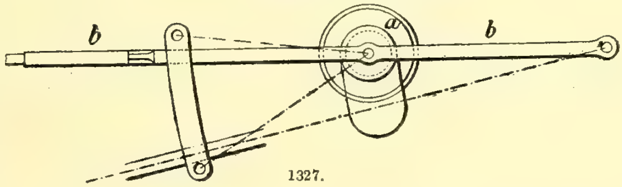


Curing.—The sticky mass of impure sugar-crystals obtained from the vacuum-pan has to undergo treatment which will separate the crystals in a pure white state. The old methods of drainage are described under the head of Cane-sugar; in the beet-sugar industry, centrifugal machines are now exclusively employed for the first operation: their principles and construction are detailed under Cane-sugar and Refining.

First, Second, and Third Sugars.—The centrifugal charged with the dirty crystalline mass is made to revolve rapidly till the colour has changed to reddish, when, without stopping the rotation, a small quantity of *clairce* (pure syrup at 30° B.) is poured in; the result of this is a clear-yellow tint in the whole mass, whereupon dry steam is injected, and soon the sugar becomes perfectly white. This is termed sugar of *premier jet* ("first throwing"). About $\frac{5}{7}$ of the total sugar recoverable in a crystalline form is thus obtained. The liquid flowing away, containing the remaining $\frac{2}{7}$ of crystallizable sugar, besides the uncrystallizable, is run into large tanks, reheated, filtered through animal charcoal, boiled to a stringy consistency, and stored in cisterns during the whole period while the first sugars are being cured. It is then passed through centrifugals, either alone, or with the addition of a little pure syrup, and thus affords a certain quantity of second sugars. The molasses drained off in the centrifugals is stored in immense tanks in a room heated to 40° (104° F.), termed the *salle des emplis* ("filling room"). At the end of a year or so, this molasses is put through a centrifugal, and yields third sugars, with which are crystallized large proportions of saline impurities.

1326.





1327.

Yields.—The results ordinarily obtained in making beet-sugar are:—100 lb. of beet afford 10 lb. of raw (uncured) first sugar, which loses 50 per cent. of its weight in the centrifugal, thus leaving 5 lb. of first sugars. The flowings from the first sugars yield 88½ per cent. of raw second sugars, which, after curing, furnish 37½ per cent. of their weight of second sugars, or 1½ lb. on the 100 lb. of beetroot. The curing of the second sugars gives a very variable quantity of molasses, which renders up 19–20 per cent. of its weight of sugar, or about ½ lb. of third sugars on the 100 lb. of beetroot. The molasses proper contains 50 per cent. of sugar, and as it amounts to 3 per cent. of the beet, it carries away 1½ lb. of sugar on the 100 lb. of beet, bringing the total yield of sugar to 8½ per cent., out of the 10 per cent. originally contained in the roots, the 1½ per cent. difference representing losses during manufacture. Thus, 100 lb. of beetroot give:—

First sugars	5·00 lb.
Second ,,	1·50 ,,
Third ,,	0·50 ,,
Molasses	1·50 ,,
Losses: sugar in the pulp	0·50 ,,
,, ,, scums	0·35 ,,
,, lost in the filters, &c.	0·59 ,,
Miscellaneous	0·06 ,,
Total	10·00 ,,

Thus the average yield of crystalline sugar from the beet is 7 lb. on the 100 lb. of root, or $\frac{7}{10}$ of what the root contains; while the final molasses takes away as much sugar (which is lost so far as its sugar is concerned) as is represented by the actual yield of second sugars.

The Molasses.—The average composition of final beet-molasses is:—Sugar, 50 per cent.; non-saccharine matters, 30; water, 20. Of the 30 parts non-saccharine matters, 10 are inorganic substances, principally potash; the other 20 parts are organic bodies, various acids united to the potash and other bases, compounds derived from the decomposition of the albumen (pectose), "betaïne," and many other substances which have not yet been isolated. These 30 parts of non-saccharine matter contain 5½ per cent. of potash, and 1·8–2·0 per cent. of nitrogen in combination. The annual production of final beet-molasses in continental Europe is estimated at 250,000 tons, representing 125,000 tons of sugar, 13,750 tons of potash, and 4500–5000 tons of nitrogen.

Until recently, the recovery of the 50 per cent. (125,000 tons) of sugar has not been attempted. The ordinary methods of utilizing the molasses have been (1) to convert the sugar present into alcohol by fermentation (see pp. 203–4), and (2) then to carbonize the residuary matters after the distillation of the spirit, and operate upon the ash to obtain the salts, principally carbonate of potash (see pp. 257–9). Some 12,000 tons of potash were extracted from beet-molasses in this way, in 1875, in 18 factories situate in France, Germany, Belgium, and Austro-Hungary. These modes of utilizing the molasses are not the most rational, inasmuch as alcohol can be produced much more cheaply and advantageously from starch. Several methods have been proposed for extracting the sugar contained in the molasses. The most important of these are Dubrunfaut's "osmosis" process, largely adopted in Russia, Germany, Belgium, and France; Scheibler's "elution" process, renowned in Germany; and various plans devised by Seyferth, Manoury, and others.

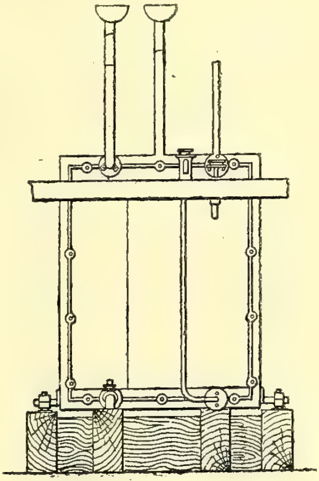
Osmosis.—The osmosis process is based on the same principles as the diffusion method for extracting beet- and cane-juices (see pp. 1842–5), the salts contained in the molasses diffusing much more rapidly through a porous diaphragm than sugar. The difference of time is, however, insufficient to enable direct separation to be made. At the commencement of the operation, the membrane is traversed by much salts and little sugar, whilst later on, the reverse takes place; the operation is, therefore, interrupted when a part of the salts is extracted, so enabling a part of the sugar to be crystallized by evaporation. The second molasses separated from the crystals is of the same composition as the first; this is again diffused, and the operation is repeated until the product is too impure to be worked further. The process is inexpensive, but it causes a loss of nitrogenous matters and potash salts, and it is difficult in some cases to get rid of the washings, which are apt to contain deleterious matters.

The "osmogene" employed in the process is shown in Figs. 1328 and 1329. It consists of two chambers, separated by a suitable diaphragm. One chamber contains molasses, while the other is filled with ordinary water, the two being parted by a septum of parchment-paper. Each compartment is a wooden frame 39 in. wide, 26 in. deep, and about ½ in. thick; 4 wooden stays divide the interior of the frame into 5 compartments, communicating by openings. On each face of the frame, are fitted leaves of parchment-paper, held up by thin cords. The molasses, entering at the bottom, rises in a serpentine into the 5 compartments of the frame, and escapes at the top. A second similar frame, filled with water, is placed in juxtaposition to the first, so that the same sheet of parchment-paper serves to separate the two frames, and consequently the two liquids. This constitutes one "element" (*couple*): several such placed in rotation form the complete osmogene. Circulation is established by channels in the frames, one at the left, below, communicating only with the molasses frames, the other, above on the right, for the circulation of water. The frames are screwed together by long bolts; they usually number 50, sometimes 100. To change the tapes, the screws are undone, and the frames laid on a table. The molasses enters at a temperature of 60°–75° (140°–167° F.), and the water at 85° (185° F.); the density of the molasses is reduced from 41° B. to 30° or 25° B. It might be still further lowered, with corresponding cost in evaporation.

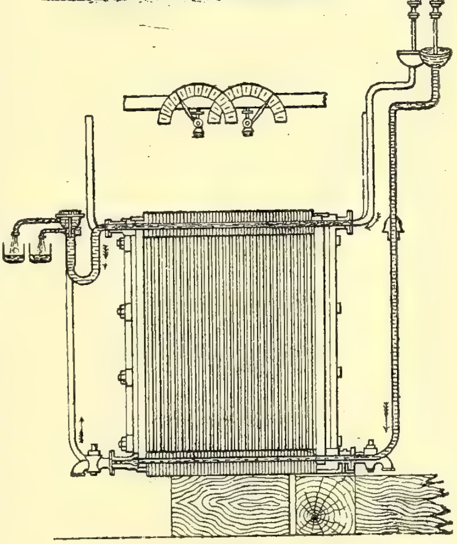
A modification of the osmogene, introduced by Lilpop, Rau, and Löwenstein, of Warsaw, takes the form of Trinks' filter-press. The frames, to the number of 51, rest by means of projections upon two horizontal arms, and are screwed together. The discharge of the apparatus and change of liquids is facilitated by arranging the whole to rotate on its axis.

Elution.—In this process, the sugar of the molasses is converted into tribasic sucrate of lime, by mixing the molasses with about a quarter of its weight of lime, when the mass solidifies; it is treated with water, which removes the organic matters, while the sucrate of lime remains solid. This latter is carbonated (like lime juice), and gives a syrup of 23° B., containing 33·7 per cent. of sugar, and 5·7 of impurities. Much sugar is lost in the washing-water; it has been proposed to remedy this by washing with alcohol of 37°, instead of water. The loss is then much less, and the exosmosis waters contain for 100 parts sugar 131 parts of total impurities. The former process is due to Lair et Bilange; the latter has been named "elution" by Dr. Scheibler.

1328.



Seyferth has modified the elution method by using molasses at 43°–44° B. at a temperature of 30°–33° (86°–91½° F.), filtered through a perforated plate to remove foreign matters. Then 30–40 per cent. of quick-lime,—free from clay, dry, and very finely powdered,—is made into a cream with water, and added to the molasses in little vats. The mass heats to 125° (257° F.); the water evaporates, and swells the bulk 3- or 4-fold. At the same time, ammonia is disengaged, in the proportion of 2·35 parts of steam for 0·008 parts of ammonia, per 100 of molasses. During the swelling-up, the mass is stirred, to prevent it running over. When the operation is finished, the whole is cooled. The vat is opened, and the cake is broken into fragments the size of a nut, without making any powder. These fragments are regularly supplied to large "elutors," having the form of diffusors, arranged in a battery, and surmounted by an outlet-tube for the displaced air, which tube plunges into a sort of condenser for the purpose of retaining the alcohol disengaged with the gases. Alcohol of 35 per cent. is introduced into the elutors from below, and remains for 12 hours upon the lime mixture. It is then drawn off, and replaced by another charge for a further 12 hours. This latter, being but slightly charged, serves for the maceration of a fresh quantity of lime mixture. The sucrate is thus treated 5 or 6 times, till at last it is quite white and pure. At this moment, steam is injected into the elutor. The alcohol which remained imprisoned in the sucrate distils, while the sucrate itself is reduced to a paste, and can be readily drawn off.



1329.

The elution process is now largely used, and furnishes, in the form of sucrate, about 80 per cent. of the sugar contained in the molasses. This sucrate may most advantageously replace milk of lime in the defecation of beet-juice (see pp. 1846–7). Opinions differ as to the relative value of osmosis and elution, the question often depending upon local conditions. The balance would seem, however, to be in favour of the latter. It necessitates expensive plant; but presents the advantages that, when the spirit is evaporated from the leys, the potash salts and nitrogenous matters are recoverable in a sufficiently concentrated form to be immediately available for agricultural purposes.

Manoury's Process.—Manoury has introduced another method for extracting the sugar from the sucrate of lime formed, and has worked it at the Capelle Factory, near Dunkerque, with complete success. The principle is the same as in the German elution process, but the application differs. Into a special mixer, is introduced the molasses with 3 per cent. of lime in the state of milk of lime of 20 per cent. The combination there takes place, and the sucrate of lime leaves it in a granular condition, not larger than a pea, and mixed with excess of pulverulent lime. A bolter separates the powder, while the grains fall into washers with alcohol at 40 per cent. There the sucrate is purified from soluble matters (salts and organic substances), and, from a deep-brown, comes out greyish. It contains about 20 per cent. of lime, and, when dissolved in water, forms a syrup of 26° B., containing an average of 15 per cent. of sugar for 1·30 per cent. of ash. About 100 lb. of molasses give 250 lb. of sucrate. The washers being closed, the loss of alcohol, including revivification, reaches only 2 per cent. of alcohol at 40 per cent. The cost of making the sucrate is placed at 7*d.* per cwt. of molasses. The sucrate is used instead of lime for carbonating raw juice. The apparatus is inexpensive, the manipulation is simple, and the alcoholic purification of the granular sucrate is very perfect.

Cane-sugar (Fr., *Sucre de la Canne*; Ger., *Rohrzucker*).—CULTIVATION OF THE PLANT.—*The Plant.*—The sugar-cane is a kind of gigantic grass, belonging to the genus *Saccharum.* Most botanists ascribe all the sorts of sugar-cane to a single species, *Saccharum officinarum* [*Arundo saccharifera*], supposing all the forms now met with to be varieties induced by cultivation. The best authorities are not absolutely agreed upon this subject, however; and it is probably impossible to arrive at a reliable decision, while the original home of the sugar-cane remains unknown.

Varieties.—Practical ends are served by a knowledge of the characteristics developed by education in the different varieties. Many of these have been raised to the level of distinct species; but it will suffice here to give the names by which they are generally known to planters.

1. The Bourbon cane, introduced into the W. Indies from Bourbon, came originally from the coast of Malabar, there growing as a small-sized, but soft and juicy cane; affected by the change of climate and soil, and cultivation, it so increased in size and richness that it at length entirely superseded the old species.

2. The Otaheite canes are two; the yellow or straw-coloured, and the purple-striped or ribbon. The former and the Bourbon are much alike, if they are not the same variety. With a good soil and favourable season, 1st year's plants are often 12–14 ft. high, 6 in. in circumference, and with joints 8–9 in. apart. Such yield (in Jamaica, Bengal, and the Straits) 2½–3 tons of sugar per acre. They attain maturity in 10–12 months, and require a generous soil, and attentive management. The purple-striped Otaheite cane is often called the Otaheite ribbon cane, in contradistinction to the ribbon cane of Batavia. It is hardy and esteemed, of large size, soft, juicy, and sweet.

3. Batavian canes are four, viz., the yellow-violet, purple-violet or Java, "transparent" or ribbon, and Batavian proper. The "yellow-violet" differs from the Bourbon in being smaller, less juicy, considerably harder, of slower growth, and more erect. When ripe, its rind is thick and pith hard; but its juice is rich and abundant. It grows in inferior soil; its sugar is of fine quality, but less in quantity than from the Bourbon. The "purple-violet," or large black cane of Java, is as thick as the Otaheite, with joints 3–7 in. apart, and is 8–10 ft. high. It yields a very sweet rich juice, but being very hard, it is difficult to crush, and affords a comparatively small quantity of juice. It is very hardy, thriving well in poor dry soils: in Jamaica, it is often planted in the outer rows, to stand the brunt of trespassing cattle. The "transparent," or ribbon cane, is much smaller than the Otaheite ribbon cane. It grows 6–10 ft. high, with joints 4–8 in. apart, and 4 in. in circumference. It is generally planted in light sandy soils, where no other cane will thrive. Though its rind is thick, and its general texture hard, yet it yields a good quantity of juice of excellent quality. The Batavian cane is common in the Straits of Malacca, where it is cultivated by the Malays. The joints are seldom more than 3–6 in. apart. In height, size, and foliage, it closely resembles the yellow-violet; it differs in being softer, more juicy, and less hardy. In a rich soil, it is prolific, and ratoons well; but, on the whole, it is inferior to the Otaheite, while requiring an equally rich soil.

4. Of E. Indian canes, the large red canes of Assam are very juicy and sweet; their sugar is of fine grain and good colour; they are, moreover, strong in growth, and much less apt to fall over than the Otaheite, to which they are equal in size, and in quantity and quality of juice. They can be cut in 10 months from being planted. In Lower Bengal (near Calcutta), and in the Straits of Malacca, a large red cane abounds, which bears a close resemblance to the preceding. The fine red cane of Bengal is much used about Calcutta; sugar made from it by the natives shows a grain of good size, strength, and brilliancy. The black and yellow Nepal canes are large-sized and fully equal in appearance to the Assam. The small-sized canes cultivated in India are very numerous, the most common being the *kajlee* and *pooree.* They are very inferior.

5. The Chinese cane possesses the advantage of being so hard and solid as to resist the white ant and the jackal—two great enemies to E. Indian sugar plantations. It is difficult to crush with the native mill, but bears drought much better than the sorts in general cultivation, producing a profitable crop even to the 3rd year, while the common cane of India must be annually renewed. It is extremely hardy and prolific; during very hot seasons, it remains uninjured in every respect. By September, it reaches 12 ft. in height, 3 in. in circumference, and with joints 6–8 in. apart. These, cut in October, may be planted out during a tolerably severe winter. The variety is well suited to India, though far inferior to the Otaheite, wherever that cane can be cultivated successfully. It is rarely more than 1–1¼ in. diam., but is sweet, and makes fair sugar. The Chinese assert that it is better adapted for making sugar-candy than any other cane. This must not be confounded with the Chinese cane experimented upon in Demerara in 1854–5, which was *Holcus saccharatus* (see Sorghum-sugar); it gave 3 or 4 crops a year, but its annual aggregate yield fell short of common cane.

6. The "elephant" cane of Cochin China has been stated to reach a height of 11 ft. and diameter of 7 in. in 6 months. It is there only cultivated for chewing, but might succeed better elsewhere. In a good soil, it requires 2 years to reach 10 ft. in height; after 5 or 6 years, it may reach 16–32 ft. In Mytho, it is cultivated in humid alluvial soils on a considerable scale. It possesses a very brittle rind, breaking into small fragments when passed through the mills.

7. The Straits Settlements grow eight kinds of sugar-cane, foremost among which is the Salangore. This is one of the finest canes known, attaining a weight of 25 lb., a length of over 13 ft., and a diameter of 3 in., under favourable conditions. It "ratoons" better than any other kind in the Straits, and has been known to yield there 40 *piculs* (of 133⅓ lb.) of granulated undrained sugar on 1 *orlong* (1⅓ acre) of ground as 3rd ratoons. As "plant canes," they have given an average of 65 *piculs* of granulated sugar from each *orlong*, or 6500 lb. to the acre, sometimes increasing to 7200 lb. They grow firm and strong, remaining much more erect than the Otaheite; and afford abundance of juice, which is sweet, easy of clarification, boils well, and produces a very fair sugar of bold and sparkling grain. The Salangore cane has been introduced into Brazil and the British and French W. Indies. Planted at 2 yd. by 2 yd., and properly manured, in 5–6 months it forms such a thick vigorous growth as to keep down weeds. The clumps yield 25–40 canes, thus producing a weight per acre much in excess of ordinary canes. As many as 16 clumps have been cut from 40 sq. yd., giving a nett weight of over 800 lb., or at the rate of more than 80,000 lb. to the acre, while the ordinary canes vary from 20,000 to 60,000 lb.

8. The S. Pacific Islands produce a number of forms of cane which are strictly local. Cuzent enumerates seven kinds in the Society Islands. On the flanks of some of the mountains, two other varieties are met with: they are both small. Canes growing in the Pacific Islands are said to yield more juice and considerably more crystallizable sugar than the bulk of those raised in our Colonies; and the Otaheite [Tahiti] canes cultivated in the W. Indies degenerate in course of time, and should be renewed by the importation of fresh stock from the Pacific groups, and perhaps New Guinea. The Sandwich Islands are accredited with 35–40 distinct varieties. One of these, grown on 30 acres of good land under irrigation, gave an average yield per acre of 12,000 lb. (6 hhds.) of No. 16 sugar. It is hardy, and grows freely up to 2000 ft. in its native country.

9. H. Prestoe recently published an official report, describing the 14 best W. Indian varieties of cane, among 32 surviving kinds of a larger number sent from Mauritius; 18 seem to be distinct varieties, deserving of culture, as possessing, in one way or other, superiority over the few sorts at present in cultivation, and among which the yellow Otaheite takes by far the largest place. Some of the new varieties are peculiar for length of joint, and some for length of joint united with stoutness. One is remarkable for these combined with very soft tissue. It also bears drought well, and is prolific. A richer and moister soil will improve all. Purple and purple-striped canes are generally admitted to be preferentially adapted, by their hardihood, to the poorer drier soils; but they have a strength of tissue which gives increased trouble in crushing. There are remarkable exceptions, however. There is no reason to doubt that, with selection and nursing, superior and fixed qualities can be obtained in sugar-cane, as freely as they have been in beet and other agricultural crops in Europe and America.

More recently, particulars have been published of three new varieties, named "Caledonian Queen," "Green Salangore," and "Violet Salangore." The first is close-jointed and extremely vigorous, and the ready way in which the length of joint and diameter of cane are affected by manure, indicates great variability of habit, and suggests gigantic growth under the influence of rich alluvial soil. The Green Salangore is the freest-growing of all, except the giant Claret cane; and its erect habit is even more striking than in that sort. In respect of length of joint and diameter of cane, it is equal to it, thus being the largest yellow cane grown in Trinidad. The foliage is completely deciduous, so that "trashing" is reduced to a minimum. The Violet Salangore has the habit of erect growth most strongly developed, besides being distinctly the longest-jointed and tallest, with a full average diameter.

The erect habit in these two Salangores is a character which, considering the influences most conducive to a large yield of sugar, is of importance. One of the most commonly observed facts on a sugar-estate is that canes grown erect (and therefore enjoying full sunlight and air) are yellow, and "full of sugar," whereas canes lying on or near the ground (and thus deprived of light and air by their erect companions) are green and deficient in sugar. The erect or decumbent posture of the canes is in a measure dependent on the soil, and on the kind of culture they are treated to, especially when young; but, under any circumstances, a marked disposition to maintain an erect habit of growth is an obvious advantage in respect of the sugar yield.

With regard to the several varieties already introduced from the East, as well as the three now newly brought into notice, there has not been any means for testing their specific habit of growth and sugar yield under extended cultivation.

The planter should make a selection of the two or three best sorts adapted to his estate, and not confine his attention to a single kind, however superior its qualities may be, for experience has proved that one class of cane, grown for successive seasons over many years, suffers material deterioration. The occasional exchange of new varieties therefore becomes imperative, in order to secure the maximum results that the land is capable of affording.

Structure and Development.—The sugar-cane has a knotty stalk, and at each knot or joint is a leaf and an inner joint. The stole or "stool" is divided into two parts: the first is formed of several (5–7) peculiar joints, placed very near to each other, and having rows of little points at their surface, which are elements of roots and are called radicles; the whole forms the primitive stole. The joints are likewise endowed with several rows of points, elements of roots, which develop themselves when requisite, and form, with the joints whence they issue, the secondary stole. The roots issue from the development of the sap-vessels, which are disposed in concentric rays round each point, on the surface of the joint. They are very slender, almost cylindrical, scarcely ever more than 1 ft. in length, and have a few short fibres at their extremities.

The number of joints on the stalk or cane proper varies from 40 to 60 (even 80 in Brazilian); but there are much fewer in the Otaheite, whose internodes or so-called "joints" are 8–9 in. long, while the finer specimens of Brazilian are but 2–3 in. The joints vary much in dimensions. The knots of the canes are rings $\frac{1}{8}$–$\frac{1}{4}$ in. wide; 4–5 rows of semi-transparent points occupy their circumference, and a circular semi-transparent line divides the outer from the inner joint. At the upper part of this, is a slight circular hollow, called the "neck," terminated by the leaf belonging to the joint. The inner joint performs the most important function of the plant from an economic point of view; in it, the juice, after undergoing various modifications, arrives at the condition which gives it its value as a sugar-yielder. On every joint is a bud, which encloses the germ of a new cane.

The sap-vessels are large, and number more than 1500. The buds always grow alternately on the opposite sides of the joints. The semi-transparent ring which forms a line of demarcation between the outer and inner joints is the weakest part of the cane, and where it is most apt to break. The rind consists of three distinct parts: the rind properly so called, the skin, and the epidermis. The rind is formed of sap-vessels, ranged in a parallel direction, on a compact circular surface. The skin, which is very thin, is at first white and tender; it becomes green and then yellow, as the joint approaches maturity. The epidermis is a fine and transparent pellicle, which covers the skin.

Under very favourable circumstances, immediately after the first development of the cane-joints which form the secondary stole, the bud of the first of these joints may throw out its radicle roots and form a second filiation on the first; the bud of the first joint of this second filiation also sometimes forms a third; the second and third soon become very nearly as forward as the first, and, like it, form canes.

The first joint requires 4–5 months for its entire growth, and, during this time, 15–20 joints spring from it in succession. When the leaves of the first two or three joints have died away, there are then 12–15 leaves at top. In its natural state, the cane has at this stage completed its growth, and arrived at the usual period of its flowering; if it blooms, the principle of life and generation passes entirely to the development of the parts of fructification. At this time, the joints which spring forth are deprived of their bud, and the sap-vessels, with which they were supplied, pass into the leaf; whence it happens that, as the number of these vessels is constantly diminishing, the joints in a similar proportion become longer, and their rind thinner. The last joint, which is called the "arrow," is 4–5 ft. long; it is terminated by a panicle of sterile flowers 18–20 in. high. If the period of flowering is delayed by cultivation, the principle of life passes to the generation of new joints, and this continues till the sap-vessels of the stole become woody, and do not afford a passage to the juices. Under cultivation, very few canes flower at all; exceptions occur on some soils, when the canes are planted early, and their vigorous growth is suddenly checked.

Range.—The sugar-cane has a wide range, succeeding in almost all tropical and sub-tropical countries, and reaching an elevation above sea-level amounting to 4000 ft. in the S. Pacific, and 5000–6000 ft. in Mexico and S. America. It is cultivated in many parts of the level country in India and China as far as 30° or 31° N. lat. Its exact geographical range may be more conveniently studied in the section on Production and Commerce.

Climate.—The sugar-cane thrives best in a warm moist climate, with moderate intervals of hot dry weather, tempered by refreshing sea-breezes. Its most luxurious development occurs on islands and sea-coasts, leading to the supposition that the saline particles conveyed to it by the winds are beneficial; but perhaps the exuberance of the plant in such situations is due to the moisture which accompanies the sea-breezes, even in the hottest and driest weather. The cane attains its greatest perfection within the tropics: cold in any degree opposes its growth and development, hence it can be cultivated but little in Europe. A singular change in the nature of the juice is occasioned by frost. While the frost continues, the low temperature prevents fermentation setting in; but should a thaw intervene, viscous fermentation takes place, and will prevent the crystallization of the juice if subsequently concentrated. In the upper districts of India, frost frequently does great harm to the cane crops. Rain at the proper season is equally necessary for cane-culture, though it may be to a great extent replaced by irrigation; but rain when the canes are maturing, if in great quantity, may do much mischief. As the canes are approaching maturity, 2–3 months of hot and fairly dry weather are exceedingly beneficial, bringing the juice to the highest degree of sweetness, and assuring a large yield of fine sugar; slight showers at long intervals serve to maintain the vigour of the plant without appreciably weakening the juice. In the case of vegetation being renewed by rains after a drought, if it occur in a locality where frost is not to be feared, it will sometimes be advantageous to leave the canes on the ground much later than usual, as the juice will gradually become much richer than it can be immediately after rain.

Should an alternation of sunshine and rain be followed by long-continued drought, the growth of the plants will be checked, and there will be a disposition to arrow. If cut now, the juice will be of good quality, but deficient in quantity, owing to the small size of the canes. When a drought sets in only a short time before commencing to reap the crop, the effect is eminently beneficial, causing an inspissation of the saccharine contents of the cells by the evaporation of their water. But if the drought should continue beyond the time necessary to produce the effects just mentioned, the stems assume a red and scorched appearance, and not unfrequently split; the canes then are said to be "burnt." The juice is reduced in quantity, and its quality is altered. In extreme cases, it is strongly acid, but it varies much in this respect. Frost will also cause canes to burst.

Soil.—Decomposed granite in the Straits Settlements affords really desirable land for sugar culture, being well fertilized by a proportion of decayed vegetable matter. In both E. and W. Indies, there abounds a kind of soil called "brick-mould," which is considered most advantageous for sugar-planting. It is a mixture of sand and clay, in such proportions that air and water can penetrate to some depth with facility, thus constituting a marl which can be worked with ease. Its property of retaining moisture, even in the hottest season, is remarkable; while in heavy rains, the water escapes quickly where drains exist. Deep black moulds are less suitable for cane-culture, tending to produce exuberant plants, rather than a rich and plentiful juice. Some of the very best sugar is produced on limestone soils, though they do not promise great fertility. In the Straits Settlements, Demerara, Louisiana, and other places, it often occurs that lands are strongly impregnated with saline matter, which causes the cane to grow most luxuriantly, but affects the juice (and consequently the sugar made from it) very prejudicially. Where salt is present in the land, as from the overflowing of tides, the course to be pursued is, after banking out the tide and properly draining, to plant Indian corn, Guinea corn, or Guinea grass for 2–3 years, until the saline matters have become in a degree exhausted; canes may then be planted without fear.

Manuring.—The object of manuring is to supply to the plant those chemical constituents which the soil is deficient in. The sugar-grower's efforts must be directed to the production, not of the tallest and stoutest canes, but of the greatest possible quantity of crystallizable sugar.

Composition of the Canes.—Before discussing what cane-manures should consist of, it is necessary to know the composition of the canes to be grown, and of the soils to grow them.

The average composition of a fully-developed sugar-cane is:—

Water	71·04	Derived almost wholly from the air.
Sugar	18·02	
Cellulose	9·56	
Albuminous matter	0·55	
Fatty and colouring matters	0·35	
Salts soluble in water	0·12	Derived from the soil.
„ insoluble „	0·16	
Silica	0·20	
	100·00	

Therefore 1000 tons of cane take up from the soil rather more than 4 tons of mineral ingredients, and about 1 ton of nitrogen is required to form their albuminous matter. Manures deal only with the materials supplied through the soil, except in supplementing the amount of nitrogen. The nature and relative proportions of the mineral ingredients are ascertained by analysis of the ash of the full-grown entire cane. Much discrepancy exists in the analyses of cane-ash hitherto made, which is due in part to variety of soil, different ages of the plants, and omitting the leaves.

Subjoined are some analyses of cane-ash, by Dr. Stenhouse :—

	Trinidad.				Berbice.			Demerara.	Grenada.	Jamaica.		
	1	2	3	4	5	6	7	8	9	10	11	12
Silica	45·97	42·90	46·46	41·37	46·48	50·00	45·13	17·64	26·38	52·20	48·73	54·59
Phosphoric acid	3·76	7·99	8·23	4·59	8·16	6·56	4·88	7·37	6·20	13·04	2·90	8·00
Sulphuric acid	6·66	10·94	4·65	10·93	7·52	6·40	7·74	7·97	6·08	3·31	5·35	1·94
Lime	9·16	13·20	8·91	9·11	5·78	5·09	4·49	2·34	5·87	10·64	11·62	14·36
Magnesia	3·66	9·88	4·50	6·92	15·61	13·01	11·90	3·93	5·48	5·63	5·61	5·30
Potash	25·50	12·01	10·63	15·99	11·93	13·69	16·97	32·93	31·21	10·09	7·46	11·14
Soda	..	1·39	..	..	0·57	1·33	1·64	..	..	0·80	..	..
Chloride of potassium ..	3·27	..	7·41	8·96	..	..	..	10·70	11·14	..	16·06	0·84
Chloride of sodium ..	2·02	1·62	9·21	2·13	3·95	3·92	7·25	17·20	7·64	4·29	2·27	3·83

The first seven were all fine canes with the leaves; No. 8 had no leaves; No. 9, but few; No. 10 was in full blossom, and had been manured with pen-manure; No. 11, old ratoons, manured in the same way; No. 12, young Mont Blanc canes, manured with pen-manure, guano, and marl.

The principal substances, therefore, required to be provided in an available state in a cane-soil are potash, silica, phosphoric acid, sulphuric acid, lime, and magnesia, besides a certain amount of nitrogen beyond what the plant can secure from the atmosphere. The oxides of iron and of manganese are, perhaps, also essential.

The relative importance of each substance is a difficult problem to solve. But the mineral ingredients are constantly found in the same relative proportions. It must not be forgotten, however, that the sugar-cane possesses a power of absorbing a quantity of salts from the soil, far in excess of its needs, and to the detriment of its juice. This is referred to under Soil (p. 1863), and is illustrated in Nos. 3, 7, 8, 9, and 11 of Dr. Stenhouse's samples.

Composition of Cane Soils.—The composition of cane soils may be illustrated by two analyses by Dr. Phipson, one (A), of a soil from an estate in Jamaica under canes for the first time; the other (B), from a Demerara plantation worked for more than 15 years consecutively :—

	A.	B.
Moisture	12·25	18·72
Organic matter and combined water	15·36	6·03
Silica and insoluble silicates	48·45	68·89
Alumina	13·80	2·50
Oxide of iron	6·72	2·60
Lime	0·99	0·08
Magnesia	0·29	0·25
Potash	0·11	0·10
Soda	0·70	0·09
Phosphoric acid	0·10	0·03
Sulphuric acid	0·30	0·03
Chlorine *	0·51	trace
Oxide of manganese, carbonic acid, and loss in analysis ..	0·42	0·68
	100·00	100·00
Nitrogen (in organic matter)	0·31	0·05

* The quantity of chlorine is unusually high, which is accounted for by the proximity of a salt spring.

While A possesses everything requisite to grow canes for a number of years, B is fast approaching exhaustion. Attention is called to the greater amount of organic matter (humus), nitrogen, lime, and phosphoric acid in A, and to the important fact that the quantity of lime (0·08) in B is far below that of the magnesia (0·25). This last is a very bad sign, so much so that the degree of exhaustion which a soil has undergone can to a great extent be ascertained by comparing the relative amounts of lime and magnesia. The lime disappears by prolonged cultivation of the cane, whilst the magnesia remains as it was. When the lime has diminished so much as to be present to the extent of only 0·1 per cent., and then amounts to but one-third of the magnesia (though originally the lime was higher than the magnesia), the crops of cane will fall off year by year, and most careful manuring will be necessary to regenerate the soil.

Manures obtained from Foreign Sources.—The only manures fit to be used on a partially-exhausted soil are good stable-manure, well-fermented farmyard dung, or manure made from night-soil. These are natural products, and not only contain all that the plant requires, but in the proper state for assimilation. Superphosphates have little beneficial effect upon graminaceous plants (including the sugar-cane and the cereals); and though excellent special manures have been compounded, nothing can equal dung and night-soil. Dung is precluded from wide use by reason of its bulk, but a product is now prepared from night-soil and urine which well compares, in composition and fertilizing qualities, with concentrated farmyard manure. It is got by evaporating excreta as nearly as possible to the dry state ; as it holds only 12–16 per cent. of water, its transportation can be effected as easily and cheaply as with guano. Analysis shows it to contain all the ingredients of rich farmyard manure in a concentrated state, and in the same assimilable form. It is manufactured by the Urban Manure Company, at Bloxwitch and Churchbridge, and is eminently adapted for long-worked cane soils.

Perhaps the best method of using the acid superphosphate manures would be to mix them intimately with one-quarter their weight of good Peruvian guano, and one-quarter their weight of cane ash, and apply the mixture at the rate of 5–8 cwt. an acre, according to the mechanical condition of the soil, and its more or less effective drainage. A good mixture for most soils consists of Peruvian guano, cane ash (or burnt begass), and stable manure or compost heap, to which mixture one-quarter its weight of gypsum might be added. This last ingredient supplies lime, which has already (p. 1864) been alluded to as of primary importance. Lime is equally well supplied by chalk, unburnt limestone, or broken sea-shells; it should never be applied in the caustic (burnt) state.

Sulphate of ammonia and nitrate of soda act as powerful stimulants, but the plants feel a great relapse shortly afterwards. Moreover, nitrogenous manures do great harm in another way, by increasing the albuminous matters in the cane-juice, to the double detriment of the sugar, first by reducing the amount of sugar in the plant, and next by destroying a portion of the sugar in the already-extracted juice during the process of manufacture.

Manures Produced on the Estate.—The waste produced on a sugar estate consists of the following materials:—(1) The "trash," or dead leaves which are stripped from the canes during growth, as well as the "tops" which are not used for planting; (2) the "begass," or crushed cane from which the juice has been (more or less perfectly) extracted; (3) the "feculencies" collected in the clarifiers, &c.; (4) the "dunder," or wash-waters, containing salts in solution and other matters. To these must be added the night-soil and dung accumulated on an estate.

The leaves should be hoed in as fast as the trashing (p. 1867) proceeds; but this cannot be done in localities frequented by the white ant. In such cases, the vegetable matter must first be fermented in tanks under sufficient moisture to repel ants, and then ploughed or trenched in between the rows of canes. The same applies to the waste cane-tops.

The begass may be carried back to the fields by the carts which bring in the canes, and immediately ploughed or trenched into the soil. But the general plan is to use the begass for fuel, and return only its ashes to the soil. Burning reduces the ashes to an insoluble condition, and their value is greatly diminished. The question of returning the begass to the soil depends upon the circumstances that the estate requires both manure and fuel, and that the fresh begass will afford either one or the other (but not both); consequently the one not so supplied must be derived from other sources. The highly-concentrated form in which cane manures are now supplied, and the invention of furnaces for burning undried begass (p. 1876), are inducements to adhere to the current custom. Thus only the ash of the begass can be counted on as manure. This amounts to about 5 cwt. from each 100 tons of cane crushed and burned; its manurial value is 8*s.* a cwt. It should be preserved with the other waste under a shed out of the rain till used. There will probably be an additional 5 cwt. of ash from other sources (trash, wood, &c.), worth about 6*s.* a cwt.

The feculencies and skimmings, say 6 tons (from 100 tons of cane), if pressed as soon as collected, yield 3 tons of juice and 3 tons of cake; this cake, dried, with or without previous fermentation, yields ½ ton of dry nitrogenous manure, worth 3*l.* The sediment of fermenting-vats, also containing some nitrogen, say 4 cwt. when dry, would be worth 10*s.*

The "dunder," being to the extent of ⅔ used over again daily in making up the wash, would leave ⅓ to be dealt with as manure, say 800 gal. or 4 tons (from 100 tons of cane). It would dry to about ½ ton, and be worth about 3*l.*

Green-soiling, Rotation, Fallows, and Tillage.—"Green-soiling" consists in planting beans. lucerne, indigo, or other plants, between the cane-rows (when canes are first planted), and ploughing them in whilst they are green and succulent; this has a powerful fertilizing effect. Indigo planted by a drill (in regular lines), just at the commencement of the rains, may, in 2 months after, be uprooted, laid along near the roots of the young canes, and moulded over. If cut to within a few inches of the ground, when they have attained a good growth, they will furnish another fine bushy plant before the end of the rains; this may then be rooted up and moulded over as the first. The indigo-plant is continually appropriated to this end by the natives of India, although not until the colouring matter (see Dyestuffs—Indigo, pp. 858–61) has been extracted, and the plant becomes partly decomposed. The greatest good can only result from ploughing in plants whilst quite green and succulent, and the best time for the operation is just before they blossom. In Demerara, the castor-oil plant (see pp. 1380–2) is highly esteemed for the purpose; and the same may be said of the pigeon-pea (*Cajanus indicus*) in the W. Indies and Australia.

Rotation of crops as a means of refreshing the soil has long been known and applied in European agriculture, and some sugar-planters have at last appreciated the advantages to be derived from it. In Mauritius, it is now becoming the general custom, after the land has borne canes for 2 seasons, to plant it with maize (Indian corn), arrowroot, manioc (cassava), or peas, allowing a period of 3 years between the cane crops.

Fallows and tillage may be considered together, as there is very little good in allowing land to lie fallow (unoccupied by any crop) without subjecting it to thorough tillage, so as to open it up, and expose it thoroughly to the action of the air. Green-soiling is probably more beneficial than merely allowing the land to lie fallow. In Demerara, rotation is rarely practised, the same land growing canes for many successive years; but care is taken to manure well, and to make constant interchange of plants between different estates.

Laying-out an Estate.—The laying-out of a sugar estate is a much more complicated affair in British Guiana than elsewhere, as it mostly includes provision for drainage and irrigation. Here the plantations are mostly narrow rectangular strips of land, with a water-frontage varying from 100 to 300 Rheinland *ruthe* or roods (of about 12½ ft.). Every estate is bounded by 4 dams: the front dam excludes the sea, river, or canal; the back dam excludes the bush-water, which, in heavy weather, would inundate the cultivation. The clay thrown out in forming the adjacent canals or trenches affords the material of which the dams are formed. Along each of the remaining sides, runs a dam from front to back, usually termed "side lines"; they serve two contiguous estates, and prevent the influx of water from the sides. The dams answer the purpose of a road round the estate; but the produce is brought to the buildings (often situated in front) by canals. The arrangement of the navigation system is very simple. From front to back, through the centre of the estate, runs a dam called the "middle walk," with a canal on each side, termed "central canals," wide enough to admit two punts abreast. The dam forms a path for the cattle that draw the punts. At intervals, branch canals strike off at right angles, and proceed to within a rood of the draining or side-line trenches, which are parallel and adjacent to the side dams. These branch canals constitute the transverse boundaries of the fields, and navigation canals thus lie on three sides of every field, and admit of canes being carried by a short path to the punts. On some estates, there is only a single central navigation canal. These canals are principally supplied by the rain, but in protracted droughts, and especially when they are shallow, they are liable to run short of water: hence, whenever access can be got to creek-, lake-, or bush-water, it is brought from behind to supply the navigation system. In other instances, salt water has to be taken in from the front. The drainage of the estate is equally simple. From back to front, and immediately adjacent to the side-line dams, run the 2 main draining-trenches, generally dug considerably deeper than the navigation canals. The small drains, again, cut at distances of 2–3 roods apart, commence within a bed of the middle-walk side of the field, and terminate in the side-line draining-trenches, having a fall in that direction. The small drains are thus at right angles to the main draining-trenches. In the front dam, the sluices or "kokers" are placed. Sometimes there is one on an estate, but generally two, one at the end of each draining-trench. The main draining-trenches are generally connected by a trench running behind the front dam.

Drainage.—The proper drainage of a sugar estate is a most important matter. This is especially the case in localities which possess no natural means of taking off the surplus water, as for instance, the flat lands of British Guiana. Open drains are at present the only ones in use on almost all sugar plantations. Besides being very ill adapted to the purpose, they entail great expense yearly to keep them clean. But perhaps their greatest disadvantage is the extent of land they occupy. On an estate of 500 acres, no less than 50 acres are lost in drains alone. Moreover, however well constructed, the sides are perpetually slipping in, and greatly preventing the flow of water. Other drawbacks are the inability to use the plough or tilling-machine, and the loss of fine earth which is being continually swept away during rainfall.

The remedy lies in the adoption of tile drains on ordinary soils, and stone box drains on heavy clays. The objection to these is the large first outlay necessary; but this would be more than compensated for by the value of the land rendered available for culture, and the reduction in the cost of maintenance.

Irrigation.—In part of Upper India and in Peru, it is impossible to cultivate even the common native cane without constant irrigation; in the W. Indies, Straits Settlements, and many other parts, the cane is grown without other moisture than that obtained by rain. But though long periods of dry weather very frequently occur, when planters are in despair at the ruin and destruction of their crops, few recognize the value of irrigation.

River water generally contains silica, potash, oxygen, and other substances conducive to fertility, independent of the extra matters contributed during heavy rains. In the dry season, when irrigation is necessary, the water would only supply those substances ordinarily held in solution. The sugar-cane thrives luxuriantly where the change of water constantly renews the supply of dissolved silica. The potash abstracted is also restored to the soil by irrigation. In irrigating during hot weather, there is an additional benefit derived from vapour passing up through the foliage.

Propagation.—The propagation of the sugar-cane is effected exclusively by cuttings from the stems. For this purpose, none but the healthiest and most vigorous canes are selected; neglect of this point results in disease and deterioration, and, even with every care, it cannot be continued indefinitely with impunity, and sooner or later new plants have to be introduced. Every part of the stem having a perfect "eye" or bud will put forth a new plant, and it sometimes becomes necessary to utilize every portion of the sound canes in this way; but where there is room for choice, preference is generally given to the few joints nearest the leaves, usually termed the "cane-top." This is not the case in Louisiana; preference is there given to the main stalks, and tops are used only for economy sake. When planted, the eyes at the joints commence to spring forth, and at the same time a number of roots are thrown out around the whole of each joint. As the development of the shoots advances, the parent cutting gradually dies and decays, while the young shoots become furnished with perfect roots of their own.

Planting.—The land having been brought into a fit condition to receive the cuttings selected, planting is the next operation. This naturally divides itself into several distinct sections:—

Lining-out and Holing.—Regularity in the rows of cane is very important. This is attained by "lining-out" the fields with great care, by means of long lines and poles (much the same as for Coffee, see p. 693). Each field of 5–25 acres is first divided into sections by tall poles, placed say 100 ft. apart on each side. Between these are stretched long tapes carrying pieces of rag, fastened at the distance apart which the holes are intended to be. Small stakes are then driven in at the rags, each stake occupying the centre of the hole to be dug.

The distances apart and dimensions of the holes are subject to no rule. Very often, the holes are made 2 ft. apart in rows 3 ft. asunder, but much depends upon the soil and climate. Common dimensions in the W. Indies are 15–18 in. sq., and 8–12 in. deep; in Guiana, 3 ft. sq. at top, diminishing to 14 in. at the bottom, and about 8 in. deep, each plant having an area of 4–5 ft. sq. There is a growing disposition to replace hand-dug holes by furrows turned by the plough, the latter effecting a great economy of labour; ploughing is universal in Louisiana. It is generally necessary to still retain the lining-out.

Setting out the Cuttings.—The number of cuttings to be placed in each hole, or each 2 ft. of trench, is 1–4, according to their vitality and the prospects of their striking root. With good sound cuttings, 2 placed at about equal distances from parallel sides of the hole suffice; when 3 are set out, they are laid parallel with each other, and with two sides of the hole; when 4 cuttings are necessary to ensure a plant from each hole, they are commonly arranged in a square, corresponding with the sides of the hole. The three usual plans of setting out in trenches are (1) end to end at a little distance apart in one continuous straight line, (2) overlapping each other zigzag fashion, and (3) side by side obliquely across the trench. It is preferable to plant too heavily rather than too lightly.

The cuttings, when in the holes or trenches, are covered with a thin layer (say 1½–2½ in.) of earth. They thus lie sheltered from direct sun-heat at the bottom of a more or less deep hole, which forms a receptacle for moisture. The time for planting is governed by the character of the local seasons; no absolute rule can be laid down for it.

Moulding and Banking.—In about a fortnight, young sprouts push themselves up through the covering of earth; these are immediately "moulded" round with some of the soil still remaining from the hole or trench. This is repeated at intervals, as the plant grows, till the hole or trench is filled up, and further till the stem of the cane is "banked up" for a certain distance, to favour its retaining an erect position.

Weeding and Trashing.—Simultaneously with the moulding and banking, the land should be thoroughly weeded with a hoe. As the plants progress, "trashing" also becomes necessary. This consists in removing from the stem every dry and fading leaf. In rich land, it requires to be frequently resorted to during the wet season, but may be done at longer intervals when the rains are over. Constant trashing admits to the plants that abundance of light and air which is essential to the production of a heavy crop of sugar. Green living leaves must on no account be removed. Equally demanding removal when too numerous, are the suckers thrown up by the roots; in Louisiana, however, they are encouraged. Both leaves and suckers should be buried in trenches between the cane rows, and covered with a thin coating of earth; there they decay, and form excellent manure for the growing crop.

Ratooning.—The first crop from newly-planted cuttings is called "plant" canes; when these have been cut, the stole or "stool" sends up another growth of canes, which are termed "ratoons." The first crop of ratoons is designated "first ratoons," and so on progressively. Ratoons annually diminish in length of joint and circumference; but they are said to yield richer juice and finer sugar. On some soils, it is found best to depend chiefly on ratoons. A very general practice is to plant a proportion ($\frac{1}{3}$) of the land in annual succession. The stoles remain in the ground, and vacancies are filled up as they occur. By constant ratooning, the produce of sugar per acre, if not equal to that from plant canes, yields, perhaps, in the long run, quite as much profit to the grower, if the relative proportions of the labour and expense attending the two methods be considered. As soon as the canes are cut, the land intended for ratoons requires attention. The trash should be buried with other manure about the roots of the plants, the earth around being well loosened and cleared of all weeds, before the rains set in. The number of ratoons depends much on the productiveness of the soil. A good rule in most cases is to replant when ratoons give only 1–1½ hhds. of sugar per acre.

In some countries, as Bengal, good ratoons are never met with. First ratoons may be allowed, but white ants swarm in the old roots, and do mischief to the growing canes; whereas when planted yearly, or every 2nd year, the stirring which the land receives drives them away. In replanting, the old roots should be burnt, and the cuttings planted between the rows of the former crop.

Harvesting.—When the canes are ripe and ready for the harvest, they are cut with hatchets as close to the stole as possible; thus new vigour is given to the ratoons that are to spring from the old root. The top is discarded; it may perhaps suffice to cut off only one joint with the top, from canes grown on very dry soils; but otherwise, two should be cut, for if they are immature, their juice will injure the sugar, instead of augmenting its quantity. All leaves are also stripped off; rat-eaten or otherwise damaged canes should be thrown out.

The canes, being cut, are tied into bundles for the convenience of taking them to the mill. On the mountains, they are carried by mules; in some parts, the bundles are rolled down the steep places, or shot down wooden spouts; in the plains, they are conveyed in carts, drawn by oxen, mules, or road engines, to enclosures near the mills; in Guiana, by flat-bottomed punts on canals which intersect the plantations for this purpose; wire-rope tramways have also been used to a limited extent.

Windrowing.—In Louisiana, frost so often occurs before the harvest is complete, as to have resulted in the adoption of a method of keeping the cut canes uninjured, termed "windrowing." For cane that is waiting for the mill, the usual plan is to throw into one furrow 2–4 rows of cane, so that the tops of the last will cover the butts of the preceding. The proper way to windrow cane for seed is first to throw to the centre of the water-furrow one or two furrows of dirt from each side; a harrow is then run over to pulverize it thoroughly, and give the cane a soft bed, at such an elevation that the cane cannot be injured by water standing on it. Upon the cane, 2–4 more furrows of dirt are thrown, to protect it from the cold. Some are in favour of "round mats," or standing the canes upon their butts on a dry piece of land, and throwing dirt around the outside to the height of 3–4 ft.; the cane from about ½ acre is usually put in each mat. The addition of a square wooden tube, running up through the centre for ventilation, prevents dry rot. The "flat-mat" method (laying down in beds about 15 ft. wide, on elevated ground, to the depth of 2–4 ft., then lightly covered with earth) is much more common and popular.

Diseases and Enemies.—Some of these are common to both wild and cultivated cane; but others are developed upon the latter alone, and have originated in defective culture, improper or insufficient manuring, or unsuitable conditions of climate or soil.

Rats.—Rats are one of the most troublesome pests, as they gnaw the standing canes, thereby admitting air, and setting up destructive changes in the juice. Some estates have been rid of rats by rearing numbers of the mongoose; it will thrive in any climate that will grow sugar-cane.

Ants.—In some localities, white ants are a great nuisance. They are driven away by tillage; and tops or cuttings soaked for a few minutes in water tainted with petroleum will never be attacked by them.

Pou blanc.—*Pou blanc*, or more properly, *pou à poche blanche*, is a collective name applied to two species of "louse" (*Icerya sacchari* and *Pulvinaria gasteralpha*). Their ravages are familiar to the planters of Mauritius and Bourbon, and specimens of one of the species have recently been discovered in Queensland, upon canes grown from joints newly imported from Singapore. In dry hot weather, these insects frequent the roots of the canes, and do much injury to the fresh rootlets, thereby greatly retarding the growth of the plants. The young run about on the green shoots and leaves, until they find a suitable spot where they may fix themselves for life. They are armed with a long sharp probe, which they introduce into the new sap-wood, and suck away the juices of the plant, sometimes till they have quite destroyed it. They spread rapidly, and are very tenacious of life. Dr. Icery found that washing the canes with alcohol killed the insects at once, and he recommends a solution formed by boiling a mixture of sulphur and lime in water. The insects rarely appear on healthy well-developed canes, and though these remedies may prove useful for checking their ravages for the moment, their complete extermination will only be secured by attention to all the conditions required by the plants. W. Bancroft Espeut believes that the "rust" described further on is caused by these insects, being in fact abrasions produced by the young feeding on the surfaces of the leaves. The "waxy" powder which is usually described as coating the fully-matured insects, is ascribed by him to the saccharine juice of the cane. It is this exudation which forms the great attraction to the ants, in quest of which the latter scrape the lice incessantly with their mandibles, till the victims die of starvation.

Borers.—The term "borer" is applied generically to the caterpillars or "grubs" of a number of species of moths, beetles, and other insects; they are sometimes (in America) also called "worms," which is a misleading name, from its being correctly and more generally applied to a distinct class. One of the most common is *Proceras sacchariphagus*, long dreaded in Ceylon, and the cause of great destruction in Mauritius, since its introduction in 1848. Two kinds prevalent in British Guiana are *Sphenophorus sacchari*, and the *tacuma*, a large species of *Rhyncophorus*, very like *R. Zimmermanni*, but not identical with it; another is *Phalæna saccharalis*, which produces 6 generations in a year. The grub of a beetle (*Tomarus bituberculatus*) also has recently given much trouble in that colony. The list might be greatly extended. The habits of the grubs appear to be nearly identical in all cases. They are provided with powerful mandibles, and their mouths are armed with lance-like instruments, which enable them to pierce the silicious (flinty) outer rind of the cane. Once within the soft juicy mass of the interior of the cane, they effect its destruction with extreme rapidity, and the juice is rendered useless. Among the means to be adopted against these insects, are the encouragement and cultivation of their natural enemies. Principal among the latter are ants, which attack the insects both in their caterpillar state, whether just issued from the eggs or about to enter the "pupal" condition (commencing to spin their cocoons), and in their perfect or "imago" form, i. e. as moths or beetles. Turkeys and the smaller insectivorous birds devour enormous numbers of the "grubs" (caterpillars). Bancroft Espeut has had singular success in cultivating other enemies of these insects, notably the Ichneumonidæ ("lady-bird beetles"), by planting a hedge of the Congo or pigeon pea (*Cajanus indicus*) around each field, and growing the bonavist bean (*Dolichos Lablab*) and pigeon pea on fallow fields, ploughing in the latter as a green-soil manure afterwards. When the estate is quite overrun with the caterpillars, it may be necessary to burn all vegetable matters likely to harbour them. But this should be avoided if possible, as it entails the destruction of the best manure the land can have (see p. 1865). The abundant application of lime to the soil is generally very beneficial in destroying the insects, besides its manurial value (see p. 1864). A widely-adopted plan is to cut off and burn the first shoots that spring from the planted cuttings; these are allowed to grow for about three months, by which time the grubs will have congregated on them. The second crop of shoots soon appears; and their skins are tougher, and better able to resist the attack of the grubs which have escaped burning. Not only borers, but many other injurious insects are propagated on the canes year after year. Hidden in the cane-tops, are the chrysalides of the insects, which in due course are transformed into moths and butterflies, whose eggs supply a new swarm of caterpillars and grubs, and thus the evil is constantly maintained. Obviously, therefore, great good may be gained by ridding the cane-tops of all vermin before planting. A very simple plan is to soak the cuttings for 24 hours in water which is sufficiently hot to destroy larvæ, without being hot enough to injure the germinating powers of the plant. More effective is the use of antiseptic preparations, as they attack parasitic growths which would be unaffected by mere warm water. Carbolic acid (see pp. 671–80) has long been used. Dr. Bancroft has published exact directions for a treatment which he has adopted with success: as follows:—(1) Carefully clean the joints of the cuttings entirely from trash (leaves), (2) immerse the cuttings for 24 hours in a mixture of 1 lb. carbolic acid to 50 gal. water heated to a degree that the hand can bear; (3) immerse the cuttings for a few minutes in milk of lime, made by mixing 2 lb. slaked lime with 1 gal. water; (4) spread the cuttings out to dry in the sun, and turn them occasionally, for one day before planting.

Rust.—A disease termed "rust" has been noticed in Queensland, the Malay Archipelago, Mauritius, the Society Islands, and Bahia. It is characterized by a dark-brown or reddish granular, incrustation, which makes its appearance on the leaves and stem, and which M'Lachlan has determined to be due to the punctures of a minute *Acarus* (mite), which exists upon the diseased cane in myriads. The creature looks very like a *Tyroglyphus*, though its habits do not altogether accord with those of that genus. A black-spored fungus is eventually produced by the red spots on the leaves; this is regarded by Berkeley as a new species (*Depazea sacchari*); he considers that it merely occupies the already-destroyed tissues. The Bourbon canes suffer much more than any other variety. Prof. Liversedge, of Sydney University, considers that rust is not a disease, but rather a result of an existing diseased condition. This he ascribes to bad cultivation, want of drainage, and improper manuring, to which must be added, in some instances, unsuitability of climate and poverty of soil.

Smut.—In Natal, the canes are attacked by a kind of "smut" (*Ustilago sacchari*), analogous to the well-known disease which affects the cereals of this country; it is entirely due to faulty cultivation.

Yields of Canes and Sugar.—Statistics of the cane and sugar production of certain districts are useful for reference in drawing conclusions as to the results of new processes.

Barbados.

1 ft. sugar-cane weighs about ¾ lb.
1 clump „ „ „ 54 lb.
1 „ „ yields „ 4 gal. juice.
4 gal. juice „ „ 4 lb. muscovado sugar.
1 acre ripe cane (holes 6 ft. × 5 ft.) yields 1452 clumps.
1452 clumps cane yield about 5808 gal. juice.
5808 gal. juice „ „ 5808 lb. sugar.
1 acre, planted 6 ft. × 5 ft., at 50 lb. to the clump, will give 72,600 lb. or 36 tons ripe cut cane, or 2½ tons raw sugar.

Louisiana.

1 acre yields 44,000–60,000 lb. cane.
The average cost per 2200 lb. is 2½–5 dol.
The density of the juice varies from 6° to 10° B., and averages 8°–8½° B.; 8° B. is equal to 14·4 per cent. pure sugar per 100 lb. juice, or 12·96 lb. sugar for the 90 lb. juice contained in 100 lb. canes; 8½° B. would mean 15·33 per cent. pure dry sugar.
1240 gal. juice at 8½° B. produce 1048 lb. sugar, and 480 lb. molasses; with the best modern machinery, more sugar and less molasses is got.
1 gal. juice at 8½° B. weighs 10·62 lb.
1240 gal. „ „ 13,169 „
100 lb. cane contain 90 lb. juice.
12,345 „ yield 11,111 „
11,111 lb. juice at 8½° B. should give 1700 lb. sugar.
The actual yield of combined sugar and water of crystallization is 14·89 per cent.
11,111 lb. juice therefore afford 1655 lb. sugar and molasses.
Of the 1655 lb., 1173 lb. are sugar, and 482 lb. molasses.
Thus 427 lb. sugar and molasses are lost in the manufacture.
11·8 lb. cane give 1 lb. sugar and 0·48 lb. molasses.
10·5 lb. cane would have given 1 lb. sugar and 0·66 lb. molasses, if no loss had occurred.
7·26 lb. cane would give 1 lb. sugar, if there were no loss, and no molasses produced.
1 acre will grow 13,000–45,000 canes.
The length of the canes varies from 3 to 8 ft.
„ weight „ averages 10 oz. per ft.
Canes 4½ ft. long, weighing 3 lb. each, and growing 350 per row of 100 ft., will give 61,125 lb. canes per acre.
Planters require 35–55 lb. cane to make 1 lb. sugar and 0·66 lb. molasses.
The average for the State is 2·25 lb. sugar and 1·50 lb. molasses from 100 lb. cane.
Thus 100 acres give 6,000,000 lb. cane, affording 135,000 lb. sugar, and 90,000 lb. molasses.
But 6,000,000 lb. cane, if no loss occurs in manufacture, can give 571,428 lb. sugar, and 380,952 lb. molasses.
And, if made into first, second, &c., sugars, could yield 750,000 lb. white sugar, and 140,000 lb. molasses.
While the same cane would make 867,510 lb. concrete sugar.

Mauritius.

1 barrel cane juice weighs 530–544 lb.
1 „ „ yields about 95 lb. sugar
1 acre cane produces 3500–5500 lb. sugar.

Egypt.

1 acre cane affords about 500 lb. refined sugar.

Juice from 100 lb. Cane.

100 lb. cane giving juice at 10° B. will yield :—

4·714 gal. juice at 50 °/$_0$ extraction.	7·543 gal. juice at 80 °/$_0$ extraction.
5·185 ,, ,, 55 ,, ,,	8·015 ,, ,, 85 ,, ,,
5·657 ,, ,, 60 ,, ,,	8·486 ,, ,, 90 ,, ,,
6·128 ,, ,, 65 ,, ,,	8·958 ,, ,, 95 ,, ,,
6·600 ,, ,, 70 ,, ,,	9·430 ,, ,, 100 ,, ,,
7·071 ,, ,, 75 ,, ,,	

Composition of Cane-juice.—Before detailing the many processes and apparatus used in making sugar, an idea must be gained of the nature and characters of cane-juice. Mention has already been made of the structure of the sugar-cane. Within the cells, is contained a sweet watery juice, a sugar-water holding a variable quantity of organic and mineral matters in solution. This is the juice which is extracted for the purpose of being made to yield its sugar. The nature of the ingredients composing it is not liable to variation; but their proportions fluctuate with the soil and climate, the age of the cane, the portion of the cane affording the juice, and other circumstances. R. H. Harland states the composition of some cane-juices expressed from ripe canes grown in Queensland, as follows :—

	Guinghan Cane	China Cane.	Mixed Canes.
Density at 15½° (60° F.)	11·5° B.	10·5° B.	11·6° B.
	per cent.	per cent.	per cent.
Crystallizable sugar	19·50	16·40	18·30
Uncrystallizable ,, ...	0·25	0·41	0·45
Ash (soluble salts)	0·70	1·11	0·37
Other organic matters	1·17	2·51	3·14
Total solid matters	21·62	20·43	22·26

Samples of unripe cane-juice showed :—

	I.	II.	III.
	per cent.	per cent.	per cent.
Crystallizable sugar	8·60	7·76	7·24
Uncrystallizable ,, ...	3·10	2·30	2·50
Ash (mineral matters)	0·21	0·25	0·34
Unknown organic matters	1·27	1·74	2·89
Total solid matters	13·18	12·05	12·97

In general terms, cane-juice consists of about 81 per cent. of water, 18 of sugar, 0·6 of organic matters, and 0·4 of inorganic (mineral) matters; further, about 0·5–0·6 per cent. of the sugar in the juice of ripe canes (it is much greater in unripe ones, as shown) is uncrystallizable. These substances are very intimately combined, but the juice is not of one constant quality throughout the whole cane. Thus planters reject the tops of the canes before extracting the juice. Further, the juices contained in the soft central (medullary) part of the cane are much richer in sugar than those of the nodular (the "knots") and cortical (the rind) portions. Conversely, the saline and organic matters (other than sugar) are in increasing proportion in the harder parts of the cane; when an extra yield of juice, therefore, is obtained by the exhaustion of the harder portions, the quantity is at the expense of the quality. This has a bearing upon the question of the relative advantages of mills extracting only 60 per cent. and those getting 85 of the 90 per cent. of juice usually present in the cane.

It is now necessary to separately consider each component part (or group) of the raw juice.

The Crystallizable and Uncrystallizable Sugar.—The artificial conversion of uncrystallizable into crystallizable sugar remains an impossibility, though the latter can be readily "inverted" into the former. From experiments by Harland, it would seem that in the growing or ripening plant a conversion of uncrystallizable into crystallizable sugar does take place, the proportion of the former being markedly decreased in juice expressed 8 days after the cutting. The occurrence of uncrystallizable sugar in the juice works a twofold mischief:—(1) The uncrystallizable sugar is itself a loss, i.e. it has no value as sugar; (2) its existence in the syrup so affects the remainder as to hinder, if not prevent, the recovery of an equal quantity of the crystallizable sugar in a saleable form, for the liquid containing the altered sugar has a treacly consistence, and cannot be conveniently deprived of its water by evaporation to such a degree as will leave the unaltered sugar in a saturated solution capable of clean crystallization on cooling. Practically, therefore, it may be said that every 1 lb. of sugar rendered uncrystallizable means a loss of 2 lb. of crystallizable sugar.

The chief cause of alteration in the sugar is fermentation of certain constituents of the juice, viz. the organic matters other than the sugar. The essential conditions are mainly access of air to the juice, and a moderately high temperature. Consequently fermentation begins in the living cane, when injuries (gnawing by rats) admit air into the cells. Artificially, it is set up the moment the juice is extracted, and is maintained by the heat necessary for carrying on the manufacture, augmenting as the time is prolonged and the heat increased. Acids also provoke fermentation; they are nearly always present in a free state, as shown by the juice giving a red colour to litmus-paper. Hence the importance of rapid treatment at low temperatures, and with the least possible exposure. Fermentation does not commence in the juice while still in uninjured canes. In Louisiana, sound canes may be kept for 3–4 months after cutting, the only result being the loss of a portion of the water of vegetation. In the Philippines, sound cut canes may be kept for a week at least, despite the high temperature of an Eastern tropical summer. This seems to indicate that canes could be kept and transported long distances without undergoing loss of crystallizable sugar; but it applies only to sound canes, and the result might be different in cases where the rind was cracked or eaten into. Obviously something also depends upon the climate, as in the W. Indies and Demerara, the juice must be expressed within 48 hours after cutting, to prevent an excessive inversion taking place; this is retarded by antiseptics, and salicylic acid is now much used with this object.

The quantity of sugar in a sample of cane-juice may be approximately ascertained from its density. This is observed by a hydrometer. As the indications of this instrument refer to the proportion of solid matters in the liquid, without reference to their character, they need correction for the solids other than sugar. The following table will be found useful for this purpose:—

Baumé Degrees at 25° (77° F.).	Weight of Sugar per cent. of the Juice (indicated).	Weight of Sugar per cent. of the Juice (actual).	Baumé Degrees at 25° (77° F.).	Weight of Sugar per cent. of the Juice (indicated).	Weight of Sugar per cent. of the Juice (actual).
4	2·8	2·6	9	15·9	14·9
5	4·9	4·8	9¼	16·5	15·5
6	7·8	7·4	9½	17·2	16·1
6¼	8·5	7·9	9¾	18·0	16·7
6½	9·1	8·6	10	18·8	17·4
6¾	9·8	9·2	10¼	19·6	18·0
7	10·5	9·9	10½	20·4	18·7
7¼	11·1	10·5	10¾	21·1	19·4
7½	11·8	11·1	11	21·7	20·0
7¾	12·4	11·7	11¼	22·6	20·6
8	13·1	12·3	11½	23·0	21·1
8¼	13·7	12·9	11¾	23·7	21·6
8½	14·4	13·5	12	24·4	22·7
8¾	15·2	14·2			

The Mineral Matters.—The quantity of mineral salts in the juice of canes best fitted for sugar-making is about 0·29 per cent. of the liquid. They are found in greater proportion in the head than in other parts of the cane. The nature of the soil has a marked influence, and to it the variations in the figures must be referred. The principal mineral matters are potash, soda, lime, and iron, as oxides, carbonates, chlorides, sulphates, biphosphates, and silicates; with these, are salts of alumina and magnesia. The annexed analysis of cane ash shows the average proportions of the most important:—

Potash and soda	18·83 per cent.
Lime	8·34 „
Oxide of iron	1·99 „
Silica	11·48 „
Alumina, magnesia, and acids in combination with the bases	59·36 „

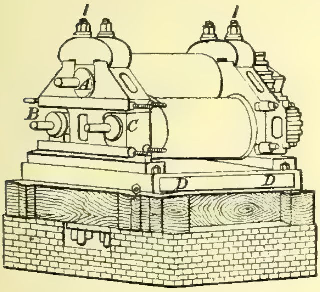
The Organic Matters.—The vegetable (organic) matters contained in cane-juice (excluding the sugar itself) may be divided into 3 groups:—(1) Substances which communicate a milkiness to the liquid, and are with difficulty precipitated from its upper layers on standing, but may be easily and almost completely separated by filtration, juice thus filtered having the property of keeping nearly 24 hours without undergoing fermentation; (2) albuminous material capable of coagulation by boiling, or even by heating to 80° (176° F.), and precipitable by strong acids without being re-soluble in excess; (3) albuminous bodies not coagulated by heat, but precipitable by alcohol and by lead acetate, and soluble in alkalies and acids (even tannic acid). Juice which has been heated and filtered may be kept perfectly fresh for some few hours, at a temperature of 30° (86° F.). At the end of this period, a thin pellicle is seen, and on the next day, a slight cream covers its surface, and the colour changes; but it is only at the end of the second day that fermentation positively shows itself. It thus appears that it is sufficient to rapidly heat the newly-extracted juice, and filter it immediately, in order to have a limpid liquid, which can be kept for a considerable time without very great alteration. Further, these substances develop acidity in the juice, and are one of the principal causes of the formation of uncrystallizable sugar. When they are eliminated, acidity is only feebly increased by the action of heat.

Extraction of Cane-Juice.—The juice in the cane exists in the plant enclosed in little cells, which are surrounded and protected by lignose (woody matter), the latter forming about $\frac{1}{10}$ of the total weight of the cane. The liberation of the juice may be effected (1) by rupturing these cells, so that their contents flow out; (2) by combining the crushing process with maceration in water; (3) by utilizing the membrane of the cells as a means of allowing the escape of the sugar and other "salts" in solution, by the process known as "diffusion."

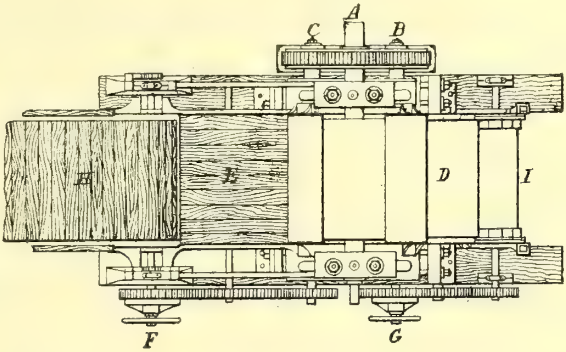
Cane-mills.—An account of all the introduced or proposed forms of mill for crushing sugar-cane would fill a large volume. Practical ends will be served by describing the typical forms.

Rousselot's 3-roller mill, as made by Fawcett, Preston, & Co., is shown in Figs. 1330–1332. The bed-plate D is seated on a strong timber framework, through which the large bolts I (Fig. 1330) pass, allowing the top roll to lift a little when any extraordinary strain occurs. The canes pass by the carrier H (Fig. 1331) down the slide E, through the rolls, and the begass emerging at D is taken away by a carrier worked by the drum I. The ordinary frame of cast iron is not exposed to tension. The resistance of the canes between the rolls A B C is taken from the top roll A through the cap and bolts, and compresses the frame, while the tendency to separate the bottom rolls is controlled by the horizontal tie-bolts; for all practical purposes, the frame might be made of oak instead of iron, as the working strains are thrown upon the wrought iron, instead of being borne by cast iron, as in other mills. The 3 cast-iron rollers are keyed on to the wrought-iron shafts. The "returner-bar," or "knife," or "trash-turner," as it is variously denominated, is a flat or curved plate, placed at a distance of 2¼–3 in. below the bottom of the top roll, made to touch the circumference of the front roll, and to stand off about ½ in. from the lower back roll, so as to allow the juice to run down. The mill shown in Fig. 1332 is composed of two cast-iron frames *d*, secured to the bed-plate *e* by bolts at the four corners. Seats are prepared on the frames *d* for carrying the brasses for the shafts of the rolls *a b c*. The bolts *i j* pass through the frames and bed-plate and through the timber *k*, and take the strain of the top roll, and the bolts *h*, of which there are 4 for each frame, take the strain on the caps *g f*. In this manner, the strain is borne by the wrought-iron bolts instead of being thrown on the cast-iron frames, enabling more juice to be extracted with safety than can be done with the ordinary cast-iron frame. The yield of sugar from the cane crushed in this mill at the central factory in St. Lucia, during the season ending in May 1881, is stated at 8 per cent. of the weight of the cane; the cane there seldom gives juice of 10° B., yet by the careful use of a Rousselot mill and the necessary adjuncts, with a

1330.



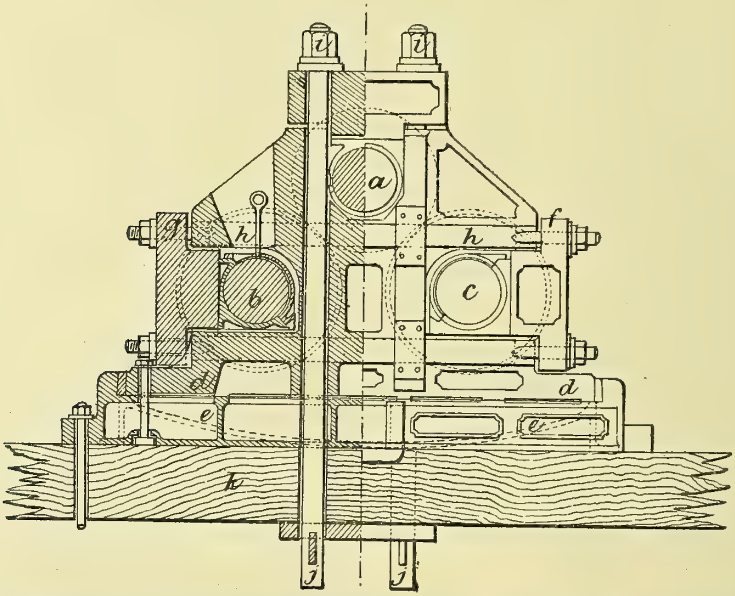
1331.



very limited consumption of animal black, 10,000 tons of cane give 800 tons of sugar of superior quality, averaging in London 25*l*. a ton.

Formerly the returner-bars were much slighter than those ordered and supplied at present. When canes are passed through a mill without choking, everything works smoothly; but from the moment that a cane doubles up, trouble begins. The rolling friction of the mill is a light matter; but the sliding friction in the confined space between the top roll, the front roll, the returner-bar, and the back roll, is very great. If the returner-bars are slight, they bend by the pressure, and the jaw is relieved. The bar is taken out and straightened, and work is resumed. A pressure of 50 lb. a sq. in. drives the mill when there is no jamming; but 80 lb. is required when it is "braked" by accumulation of trash between the rolls and the returner-plate; orders are daily given for stronger returner-bars, so that where the massive rolls are "braked" with trash, that becomes hot and hard with friction, the resistance has to be overcome, and returner-bars are made to resist the force of a 60-H.P. engine, geared 20 to 1, and making 40 rev. Many engineers contend that those who are trying to increase the yield in juice by very slow movement are in error, and recommend experiment in the direction of lighter and repeated crushings, combined with maceration. By using two mills of moderate proportions, more effective work is said to be obtained, because there is less sliding friction; and it is questioned whether the extra quantity of juice obtained by the extra force of a large mill is not at the expense of the quality.

1332.



On the other hand, the rolls of the mills erected at Aba-el-Wakf, by Eastons and Anderson, in 1872, measured 48 in. diam. and 5½ ft. long, had a surface-speed of 27–36 ft. a minute, took a feed 15–18 in. deep, and did excellent work. A comparative trial of a small rapid and a large slow mill on the same estate in Porto Rico, under like conditions, is interesting. The rapid mill had rollers 22 in. diam. by 48 in. long, and an average speed of 24 ft. a minute; the slow mill had rollers 36 in. diam. by 66 in. long, and an average speed of 9 ft. The rapid mill ground cane in good season, yielding juice of 10° B., and having 10 per cent. of woody fibre; the slow mill had average good canes, a little over ripe and dry, yielding juice of 11° B., and 14 per cent. of woody fibre. The results were:—

RAPID MILL.

Quantities.	Canes in lb.	Juice in gallons.	Juice in lb.	Sugar in lb.	Molasses in lb.	Total Green Sugar.
387 loads ..	1,170,332	65,442	702,092	72,081	37,464	109,545
1 load ..	3,024	169·1	1,814·44	186·25	96·80	283·05
100 lb.	100	5·59	59·9	6·16	3·20	9·36
1 gal... ..	nearly 18	1·00	10·73	1·10	0·572	1·672

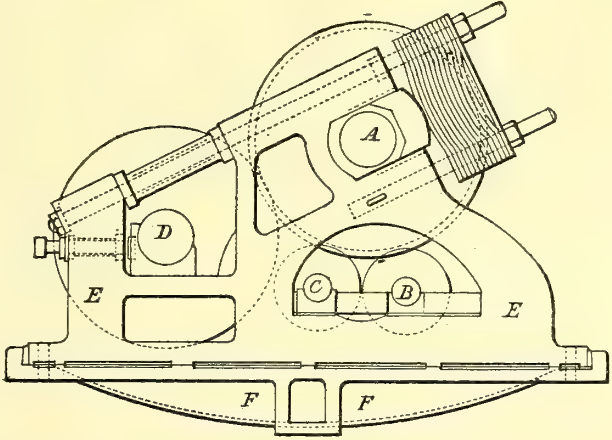
Slow Mill.

Quantities.	Canes in lb.	Juice in gallons.	Juice in lb.	Sugar in lb.	Molasses in lb.	Total Green Sugar.
629 loads ..	1,369,275	98,350	1,063,163	138,750	64,944	203,694
1 load ..	2,177	156·36	1,690·25	220·6	131·67	352·27
100 lb.	100	7·18	77·61	10·13	4·74	14·87
1 gal... ..	13·07	1·00	10·81	1·41	0·66	2·07

The loss in the begass of the rapid mill was 7·53 per cent.; in that of the slow mill, 2·47, or a difference in favour of the latter of 5·06 per cent.

The De Mornay mill (Fig. 1333) presents various advantages, and will doubtless be more widely adopted in future. In Cuba and Demerara, it is unknown; but it has been manufactured for S. America by Fawcett, Preston, & Co., and worked there with great success. The canes enter between the rolls A B, and are carried onwards by the roll C, inclining upwards until they are grasped by A D. There is no returner-bar in this mill to cause abnormal friction and resistance, and no sliding or rubbing of the top roll on a mass of crushed cane. It is stated that this mill, when properly constructed and proportioned, will grind cane with 50 lb. steam when the ordinary 3-roller mill fitted with a returner-bar requires 65 lb., or the difference between a 15- and a 20-H.P. engine.

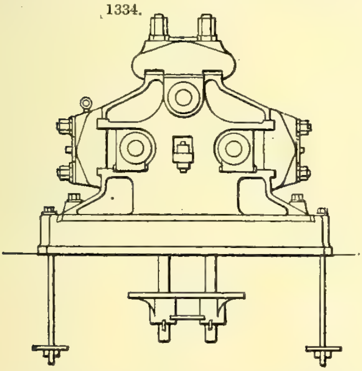
1333.



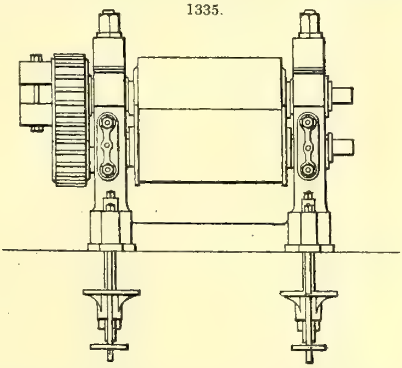
Figs. 1334 and 1335 show end and front views of the 3-roller mill made by Manlove, Alliott, Fryer, & Co., of Nottingham and Rouen. The bed and cheeks are entirely of cast iron, carefully proportioned to its work. Strong wrought-iron tie-bolts take the main tensional strains in the mill. The side roll-caps, while well established when the mill is working, are readily removable, and the rolls can be slid out without any lifting.

Cane-mills have been constructed with 4 and even 9 rolls. In the 4-roll mill, where 2 rolls are placed above and two below, the driving-power is said to be not much greater than that required for an ordinary 3-roll mill, while more juice is obtained; but this statement is very doubtful, and is negatived by the fact that 3-roll mills have quite superseded the 4-roll arrangement. In the 5-roll mill, 3 rolls are placed below, and 2 above; 10 per cent. more juice is said to be extracted by this plan, but much greater power is needed, and the begass is much broken up.

1334.



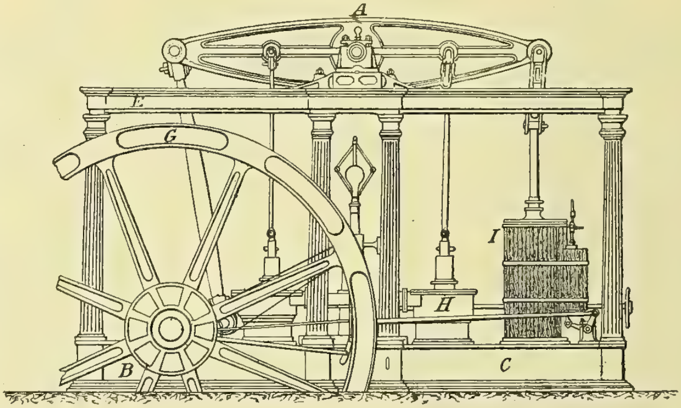
1335.

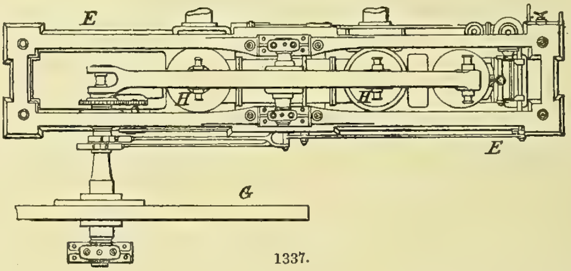


Motors.—With regard to the suitability of the several kinds of power for driving cane-mills, it has been ascertained, by comparing the results of 44 mills in Guadeloupe, that:—with windmills of inferior construction, the cane-mills extracted only 50 per cent. of juice; with ordinary windmills, 56·4 per cent.; with animal power, 58·5 per cent.; with water power, 59·3 per cent.; with steam power, 61·8 per cent.

Figs. 1336 and 1337 show an economical combination of a vertical beam-engine arranged so as to work two large air pumps, and with power enough to work the cane-mill at the same time. This style of engine is applicable when the sugar-factory is organized so as to run day and night, as all should to work profitably. The engine is constantly at work, and its exhaust-steam is as constantly absorbed by the juice. It is evident that by using one large engine instead of three (one each for the cane-mill, the triple-effect, and the strike-pans), much loss by friction and expense of attendance are saved. In the figure, E represents an entablature carrying the beam A, mounted by 8 columns on the bed-plate C; H are two large air-pumps in connection with the triple-effect and vacuum-pan; a massive fly-wheel G is necessary to secure regularity of motion.

1336.





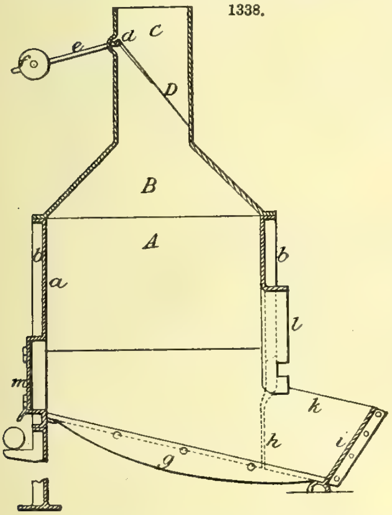
1337.

Fuels and Furnaces.—The use of coal and wood as fuel needs no remark. Whether wisely or not (see p. 1865), begass is largely employed for this purpose. Approximately, 2 lb. of begass equal 1 lb. of coal, or 16 lb. of begass to evaporate 1 gal. of water. So that the refuse of the canes should give fuel sufficient to make the sugar, when the canes are not completely exhausted of the saccharine juice. Ordinarily the begass requires preliminary drying by the sun and wind, but furnaces have lately been introduced for burning it in the wet state, as it leaves the mill.

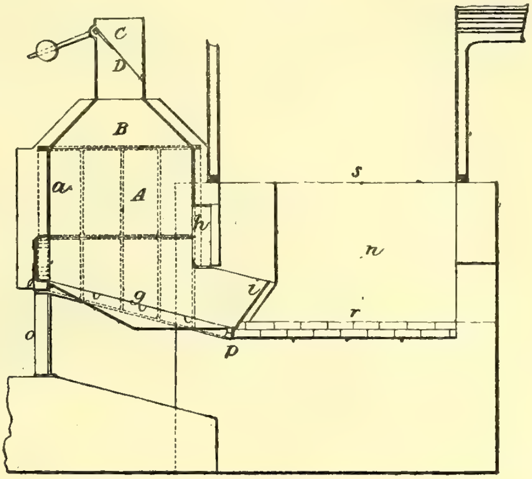
Marie's begass-furnace, made by Manlove & Co., is shown in Figs. 1338, 1339, respectively in section and as attached to a boiler fire-box. The chamber A is constructed of cast-iron plates *a* stiffened by ribs *b*, bolted together by flanges, and encased in brickwork. The pyramidal crown B is also of cast-iron plates, bolted upon A, and surmounted by the hopper C, in which the begass is dried, and through which it is fed to the furnace. An inclined balance-door D is placed in the hopper, working on pivots at *d*, supported in the sides of the hopper, one having a lever-arm *e*, upon which is an adjustable counterweight *f*, to regulate the quantity of begass admitted. The fire-bars *g* are inclined; their lower ends extend through an opening *h*, and are supported by an inclined bridge *i*, bolted to extensions *k* of the side walls of the furnace. The upper part of *h* is surrounded by a flange *l*, the dimensions of the flanged opening being varied as circumstances may require. The doors *m* give access to the furnace. The most exposed parts of the sides *a* are lined internally with fire-brick, and the walls *n* are similarly faced. The begass-furnace is shown supported at front on feet *o*, and at back upon a wrought-iron girder *p*, whose ends are built into the walls that support the fire-box *s* of the boiler. The lower part of the boiler fire-box is completely closed by brickwork *r*, supported on girders built into the side walls; the interval between the begass-furnace and the fire-box being also built up, the air to support combustion must come in through the fire-bars *g*.

Begass coming wet from the mill requires to be dried to render it fit for fuel, and it receives its preliminary drying in the external furnace. A coal fire having been first lighted in A, its walls become highly heated; the wet begass is then fed in through C, whose balance-door D gives passage to and spreads the begass uniformly upon the grate *g*, closing again immediately to re-establish the draft through the grate. In this arrangement, the heat which would go to evaporate the water, is stored up in the walls of the furnace, which quickly become hot enough to almost instantly dry the begass, and render it eminently fit for burning. As all the gases are compelled to pass through the mouth leading to the boiler-furnace *s*, perfect combustion is ensured, and there is little or none of the usual deposit in the boiler-tubes. The advantages of a furnace which will burn wet begass extend to the important gain represented by the avoidance of risk of fire, constantly to be feared when dried begass is stored in large quantity. The Marie furnace has been applied also to the "copper walls" for making muscovado sugar.

1338.

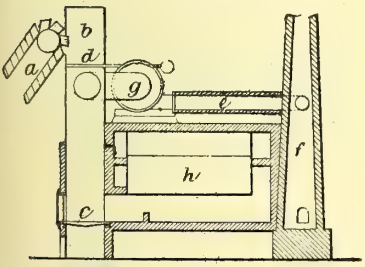


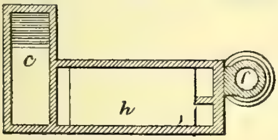
1339.



Norbert Rillieux, of Paris, also has a plan for drying the begass on its way to the furnace. His apparatus is shown in Figs. 1340, 1341. The wet begass is delivered by elevators *a* into the hopper *b*, leading at bottom into a chamber communicating with the furnace *c* of the steam-boiler *h*. In this hopper is a hinged horizontal flap *d*, on which the begass falls, and which is held by a balance-weight till the load accumulated upon it overbalances the weight, when the begass is discharged down the chamber, and passes into the furnace to be burnt, the flap being closed again by the balance-weight. While the begass is retained in the hopper, and descends through the chamber, it is subjected to currents of hot gases from the furnace, so as to become dry before passing into the fire. The hot currents may be accelerated by connecting the hopper by a pipe *e* with the chimney *f* of the boiler, the draught being regulated by a throttle-valve; and if required, a blowing-fan *g* may be provided in the pipe, and regulated so as to produce the required degree of desiccation.

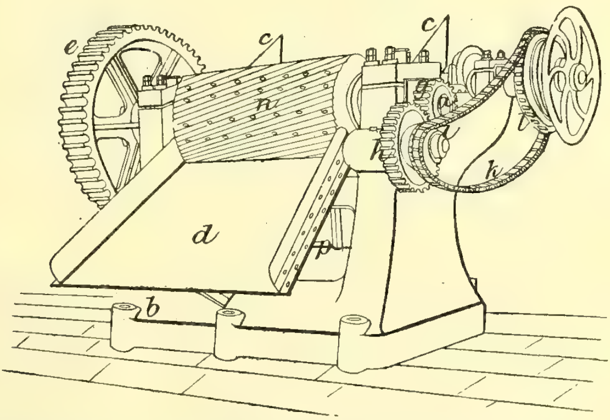
1340.





1341.

1342.

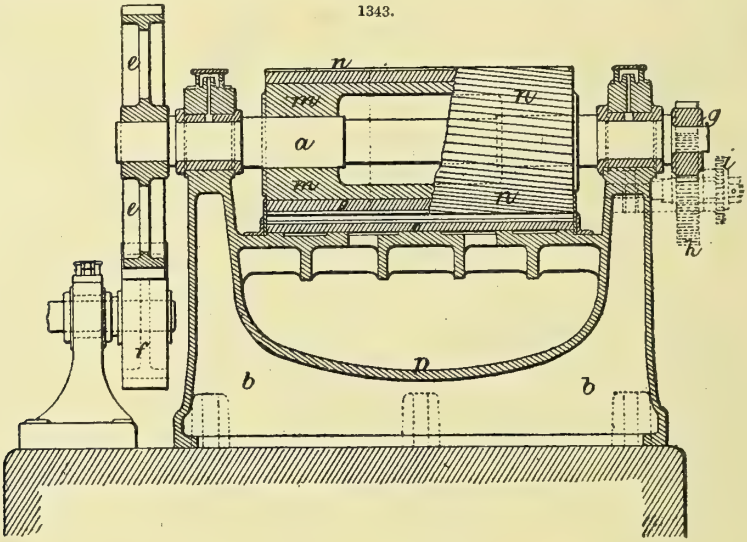


Disintegrating.—The imperfect liberation of the cane-juice by the crushing process of the ordinary mill has led to experiments in other directions. One result has been the invention of machines for effecting a more thorough mechanical disintegration of the cane-tissue. These may be conveniently considered under three sections:—(*a*) Defibrators, (*b*) Bessemer's press, and (*c*) Bonnefin's rasper.

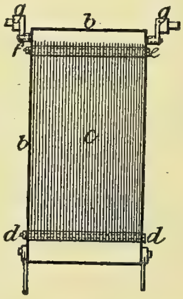
a. Defibrators.—This term (Fr. *défibreur*) is employed by several inventors. In Mignon et Rouart's, the cane is reduced to pulp, and by subsequent pressure, 77 per cent. of juice is said to be separated by the first crushing, and a further 25 per cent. on the weight of the begass by a second operation. The machinery is in operation in Guadeloupe.

Faure's defibrator, made by Manlove, Alliott, Fryer, & Co., is shown in perspective in Fig. 1342, and in horizontal section in Fig. 1343: *a* is a shaft carrying a cylinder, whose surface is provided with teeth running in a helical direction; *b*, a strong frame; an articulated cane-carrier receives its motion from the defibrator itself; *c*, inclined plane bringing the canes in front of the cylinder; *e* strong spur-wheel fixed to one end of the shaft *a*, and receiving motion by a pinion *f*; *g*, pinion fitted to the other end of the shaft *a*, and communicating movement to another spur-wheel *h*, in front of which is another toothed wheel *i* for a pitch-chain; *m*, drum of polygonal form keyed on to the shaft *a*, and to which are attached the toothed defibrating-plates *n*; *o*, a double counter-plate, formed of two distinct parts: the front part is on the feed side, where the opening is wider, and its teeth project in the same direction as those of the drum, although inclined inversely, their object being to rectify the position of canes which are presented endwise; the back or working counter-plate at the outlet side has teeth which project in the opposite direction, and effects the defibration of the canes, which it arrests and rolls on, crushing them under the teeth of the drum. The small quantity of resulting juice passes through little holes in the counter-plates, into the channel *p*, whence it is conducted to the juice expressed by the cane-mill. The canes are fed by hand or by the carrier broadside-on upon the inclined plane which conveys them in front of the defibrator. The object of the machine is to prepare the cane for the ordinary cane-mill, by breaking up the fibres and knots lengthwise. It is stated that by its use the yield of juice has been increased from 70–71 to 78–82 per cent.

1343.



1345.



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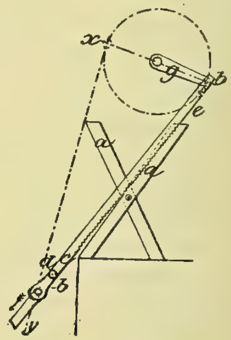


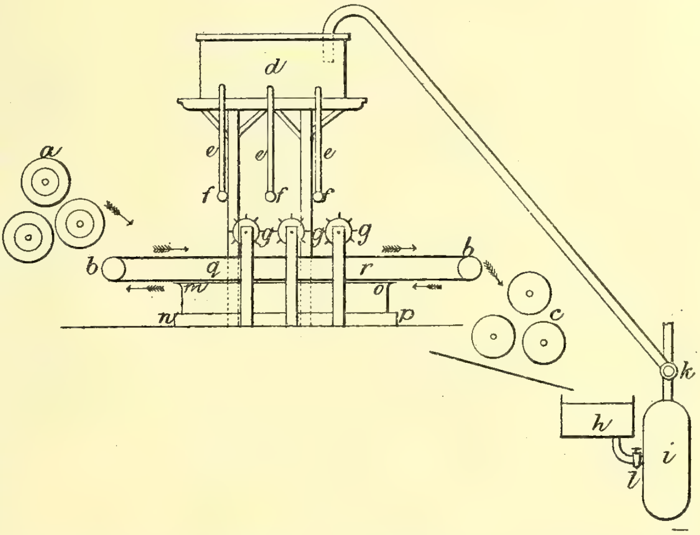
b. Bessemer's press.—An account of the cane-squeezing machine invented by H. Bessemer in 1849–52 is not necessary, as many such accounts already exist, and the machine never came into general use. The machine consisted of plungers working in cylinders, across whose path the canes were passed endwise, and were thus crushed section by section. When applied to freshly-cut canes in the W. Indies, the results fell short of the ordinary 3-roller cane-mill.

c. Bonnefin's rasper.—Fig. 1344 shows a side view of the apparatus, and Fig. 1345 a back view of the frame of saws. *a* is the rack in which is placed the bundle of canes to be cut; *b*, a frame carrying a number of parallel saws *c*. The lower end of each saw has a rod *d* passed through it, and the saws are kept apart by distance-pieces slipped on to the rod and interposed. The upper ends of the saws hook over a rod *e*, and are similarly kept apart; they are clamped and held by the screw-nut *f* screwing on to the end of the rod. The lower end of the saw-frame is jointed to rods, free to move to and fro in guides in the direction of the arrow. The upper end is jointed to a crank *g*, to which a revolving motion is given. The saws will thus alternately move through the cradle, cut through any canes placed in it, and move back into the position shown by the dotted line *x*–*y*, so as to be ready to act upon a fresh bundle of canes. When the cane has been rasped to shreds, it is reduced to pulp by disintegrating apparatus, and then the juice is separated by pressure. The predecessors of this plan were Manfold's sawdust method and Murdoch's system of cutting obliquely and disintegrating.

Maceration.—It has been sought to facilitate the extraction of the juice by submitting the cane to the action of water or steam, either before the crushing operation in the roller mill, or at an intermediate stage between two such crushings. It seems to be undecided whether the saturation or the extra crushing should be credited with the increased yield of juice. Probably both assist; but it has been stated that the return of juice is raised from 60 per cent. to 75 per cent. by previously slicing the canes longitudinally, without any application of water or steam.

Several methods have been devised for carrying out the saturating process on a practical scale, known as "maceration" or "imbibition" processes. The most important of these is Duchassaing's, shown in Fig. 1346. The mill *a* receives the canes and crushes them, giving 68 per cent. of juice. The begass falls upon an endless cloth *b*, which conducts it to a second mill *c*; *d* is a tank containing boiling water; *e* are tubes terminating in pipes *f* parallel to the endless cloth, which sprinkle water from the tank *d* upon the begass passing from the first to the second mill; *g* are beaters which turn the begass and thus equalize the imbibition; *h* is a tank which receives the juice from the mill *c*; *i* is a *monte-jus* which sends this juice, if its density is not sufficiently great, into the tank *d*, to serve for a second maceration of new begass, or, if it is dense enough, by the joint *k* to the defecation. The endless cloth *b* dips so that the portion between *q r* immerses the begass in boiling water contained in the vessel *m n o p*, thus increasing the maceration. Since the apparatus has come into extensive use, it has been simplified by dispensing with the beaters *g* and the vessel *m n o p*. The system raises the yield of sugar from 9·40 per cent. on the cane to 11·04 per cent.; it received an award of 4000*l.* from the General Council of Guadeloupe in 1876.

1346.

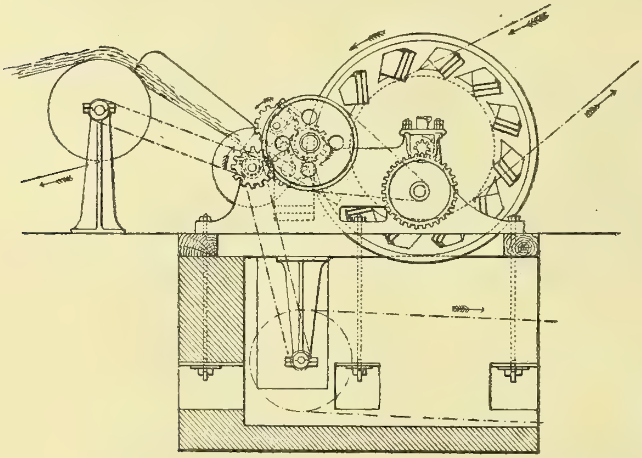


It may be mentioned on the authority of Col. Thomas P. May, the well-known American author, who was formerly a large sugar-planter in Louisiana, that auxiliary mills (double crushing) have given highly satisfactory results in Louisiana during the season just ended (1881–2). These mills are being erected by Leeds & Co., for over 50 years the largest makers of sugar-machinery in that state. Five rolls are the number adopted by this firm, and, on the Poydras plantation, one of these mills yielded the unusual result of 126 lb. of sugar from 1 ton (2000 lb.) of canes.

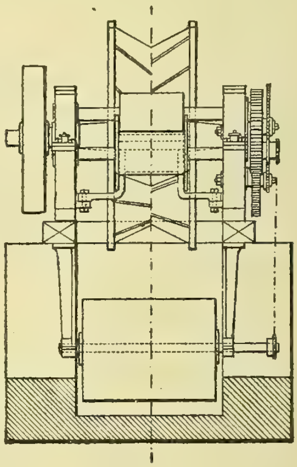
Diffusion.—All the processes hitherto described for extracting the juice from the cane have depended for success upon the more or less complete *rupture* of the juice-containing cells. "Diffusion" differs from them essentially, in dispensing with the breaking up of the cells, and the machinery required therefor. The chief development of the diffusion process has been in the beet-sugar industry (see pp. 1842–6), but several methods of applying it to cane have been introduced. The cane is even said to possess an advantage over beet with regard to diffusion, in that the nitrogenous matters are so placed in the secondary cells that water at a high temperature can be used without injuring the membrane.

Slicing-machines.—The first operation is to reduce the cane to diagonal slices 3–4 in. long, and $\frac{1}{16}$ in. thick. One of the most successful machines for this purpose is that made by A. Jouin et Cie., Paris, extensively used in Guadeloupe, and shown in Figs. 1347–1350. It consists of a disc, the periphery of which, formed like a truncated cone, either simple or double, is armed with a series of blades, whose inclination with that of the periphery is such that the sliced matters are driven by centrifugal force away from the wheel. A pair of feed-rollers, placed in front of the disc, pass forward the canes to be cut, at a speed proportioned to the capacity of the machine, and the thickness of slice desired. The apparatus is supported on a foundation-plate, fixed to the ground or the floor of the works. A suitable cover surrounds the machine, to prevent the slices being scattered, and make them fall into the pit below, whence they can be withdrawn in any convenient manner. An endless feed-apron conducts the canes to the machine, as in ordinary roller-mills.

1347.



1348.



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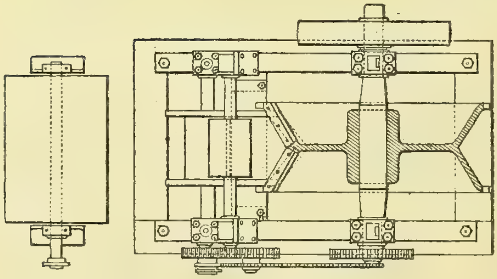

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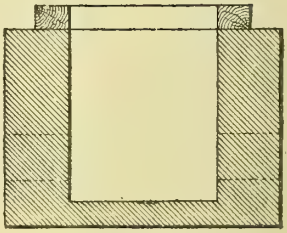


1350.

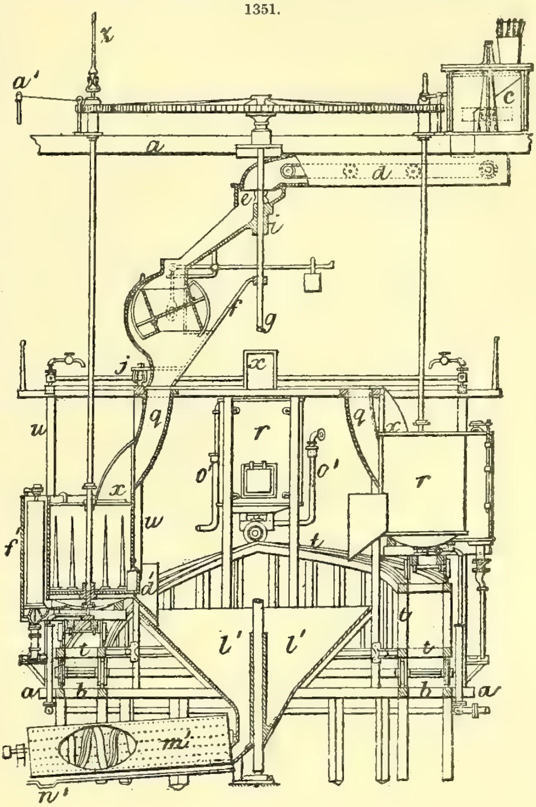
Bouscaren's System.—This system, introduced into Guadeloupe by L. F. G. Bouscaren, is shown in Figs. 1351–2. The cane as sliced at *c* is conducted in measured quantities to each in succession of a circuit of 12 open diffusors *r*, consecutively subjected to elevation and depression, so as to cause the liquor to flow by gravity from one to the other. Each has a steam-chamber for heating its liquor, that the albuminous impurities in the cane may be coagulated before they mingle with the sugar. Elevation and depression are obtained by supporting the circuit upon an annular double inclined track *b*, slowly and continuously rotated, each diffusor being held by vertical guides *n*.

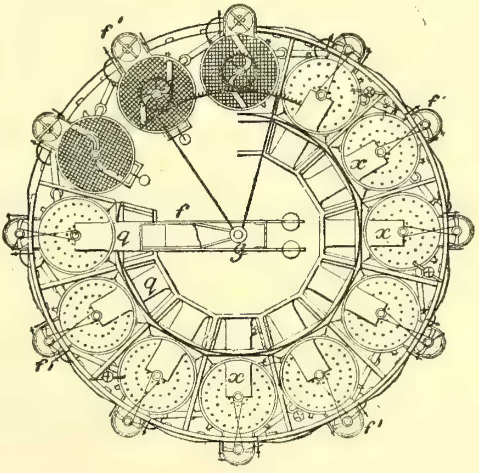
The bottom of each is kept in constant communication with the top of the one next below, by means of an extensible pipe. The apparatus is provided with means of agitating the contents; a series of straining-diaphragms and devices for keeping their meshes open, so as to retain suspended impurities without interrupting the flow of liquor; and mechanism for discharging the spent contents and cleansing the vessel, without interrupting the operation, and for straining and delivering the solid refuse.

At Monrepos, Guadeloupe, with an apparatus consisting of 6 diffusors, juice having a density nearly equal to that of the natural juice is obtained, 1½ hour being sufficient for extracting the sugar. The yield of white sugar amounts to 12½–13 per cent. of the weight of the cane.

Robert's System.—Julius Robert's process, sufficiently familiar to those engaged in the beet-sugar industry (see pp. 1843–4), is coming into use among cane-planters. The machinery required comprises a 45-H.P. steam-engine, cane-cutters, diffusion-vessels, and a heater. The cane-cutters are constructed by Franz Rebicek, of Vienna; they make about 225 rev. a minute, effect a clean sharp cut, elliptical in shape, 3–4 in. long, and $\frac{1}{8}$–$\frac{1}{16}$ in. thick, and slice up a minimum average of 6000 lb. an hour. The elliptical cut severs the maximum number of central cells, wherein the sugar is said to chiefly reside. The diffusion-vessels are of light boiler-iron with cast-iron bottoms. They measure 120 cub. ft., and contain about 4200 lb. of cane-chips and 3250 lb. of water, 10 forming a battery. Each vessel has 5 pipes—for water, to send juice to the heater, to receive juice from the heater, to discharge juice into the clarifiers, and to pass juice from one vessel to another, besides one direct from the boiler for steaming purposes, and one for discharging the water from the vessel before emptying the exhausted chips. The vessels have a manhole at top for receiving the chips, and another 4 ft. sq. next the bottom for discharging the exhausted chips. The concentrated juice is drawn from the vessel through a perforated false bottom. The heater, of boiler-iron, and in direct communication with the steam-boiler, is used for heating the juice on its passage from one diffusor to another, as it traverses a system of copper pipes completely surrounded by steam.

1351.





1352.

Hydrostatic pressure is used in passing juice from one vessel to another, through the heater, and into the sugar-house; this is obtained by a water-tank of 1500 gal. capacity, placed about 20 ft. above the diffusors. As soon as vessel No. 1 is filled with chips, and while No. 2 is being filled, direct steam is let in until it begins to escape at the top. Steam is then shut off, and water is let through the heater until the vessel is full, when the manhole is closed. No. 2 being filled with chips and duly steamed, water is again let down from the tank through the heater into No. 1, driving the liquid into No. 2 through the connecting-pipe. No. 3 is filled, steamed, and charged with juice through No. 2, in the same way. When No. 4 is filled with chips, cold water is let directly from the tank into No. 1, driving the juice which was in it through the heater into No. 2, and from 2 to 3 and 3 to 4. Next, cold water is run into No. 1, and from No. 1 to No. 2, from No. 2 through the heater into No. 3, then directly into 4 and 5, and so on, care being taken to preserve the temperature of the last vessels filled at about 88°–93° (190°–200° F.). When the hot juice has passed through No. 7, it is sufficiently concentrated, and is discharged into the sugar-house; No. 1 is now emptied, and No. 2 becomes the first vessel in the battery, and the work goes on as before, there being always 7 vessels working, one emptying and two refilling: so that practically, when the work is in full operation, as fast as one vessel is filled, a charge of concentrated juice goes into the sugar-house, and one vessel with exhausted chips is emptied. The exhausted chips are discharged through the large manhole near the bottom of the diffusor, and received on a carrier which drops them into the begass carts. A vessel is emptied by two men in 6–8 minutes, including opening and closing the manholes; filling requires 12–15 minutes.

The normal condition of the battery in regular working order is:—

No. of Vessel.	Temperature of Juice.	Specific Gravity.	Saccharometer at 63½° F.	Baumé at 63½° F.	Remarks.
I.	21° (70° F.)	1·00030	0·08	0·048	These figures correspond to cane-juice of 7¾° B.
II.	29° (85° F.)	1·00310	0·80	0·44	
III.	32° (90° F.)	1·00544	1·40	0·80	
IV.	49° (120° F.)	1·01134	2·90	1·6	
V.	93° (200° F.)	1·01618	4·12	2·3	
VI.	87° (189° F.)	1·02537	6·45	3·6	
VII.	91° (196° F.)	1·04599	11·40	6·3	

The density of diffusion-juice in practical working is 1°–1½° B. less than that of the raw juice, which gives an excess of water to be evaporated amounting to 16–20 per cent.; this entails an additional expense of about 8½*d.* on every 1000 lb. of cane, estimating wood at 12*s.* 6*d.* a cord (8 ft. × 4 ft. × 4 ft., about ⅓ ton), and coal at 3*s.* 1½*d.* a bar. (200 lb.).

The comparative characters of mill- and diffusion-juice are stated thus:—

Mill-Juice.		Diffusion-Juice.
1·05746	Specific gravity	1·04620
11·80 per cent.	Crystallizable sugar	9·65 per cent.
1·68 „	Uncrystallizable „	1·38 „
0·62 „	Foreign substances	0·42 „
14·10	Saccharometer	11·45

Diffusion ordinarily extracts nearly 83 per cent. of the juice, leaving 17 per cent. in the chips and refuse water. More can be obtained by continuing the process, but there is a point beyond which it does not pay to go, because, by drawing off more, less cane is worked up, and the greater amount of fuel required to evaporate the extra water is not paid for by the additional sugar. The 83 per cent. of juice sent to the clarifiers gives:—

Crystallizable sugar	8·81 per cent.	on the weight of the cane.
Uncrystallizable „	1·25 „	
Foreign substances	0·46 „	

The loss by clarification, skimmings, and sediments amounts to about 6 per cent. on the juice, or 4·98 on the cane; therefore the juice really obtained in green sugar is 78 per cent. of that present in the cane. Of this,—

8·28 per cent. is crystallizable sugar.
1·17 „ „ uncrystallizable „
0·43 „ „ foreign substances.

A week's run of the process in Louisiana, working up 987,945 lb. of cane, gave:—

Density of Mill-Juice.	Density of Diffusion-Juice.	Yield of undiluted Juice on the Weight of Cane.	SUGAR OBTAINED.					MOLASSES OBTAINED.			Total Sugar and Molasses in lb.	Percentage of	
Saccharometer.			In hhds. 1st Product.	In hhds. 2nd Product.	In lb. 1st Product.	In lb. 2nd Product.	Total in lb.	Barrels.	Gallons.	Lb.		Sugar on Weight of Cane.	Molasses on Weight of Cane.
14·10	11·45	82·92	29	14·5	35595	16111	51706	100	4249	50778	102,484	5·234	5·193

The water required to work the diffusion apparatus is about one ton to every ton of cane; it is important to have pure water, as it has a great influence on the quality of the juice. Water containing organic impurities in partial decomposition would add to the juice similar elements of fermentation to those which the process aims at leaving in the cells of the cane. About 6–7 per cent. of the water is saved, if, instead of emptying the water from the vessel containing exhausted chips, it is forced into the next. A peculiar difference exists between mill-juice and diffusion-juice, in that the latter requires longer to crystallize when brought to syrup. Besides this, by the continued application of high temperature, part of the crystallizable sugar is inverted, as proved by the excess of molasses. In the matter of rapidity of crystallization, diffusion-juice apparently labours under a disadvantage as compared with mill-juice; but this is obviated by supplying more receivers for the syrups, and by heating the "cooling-room." The begass forms an excellent material for paper-making. The chief drawback to diffusion is the large quantity of water required, which, though much of it can be utilized for condensing purposes, represents a proportionate extra evaporation and extra cistern space; but under favourable circumstances, the larger yield of sugar more than compensates for the extra cost.

The Robert process is in use at the Aska works, Ganjam, Madras, where the sugars made by it analyze:—

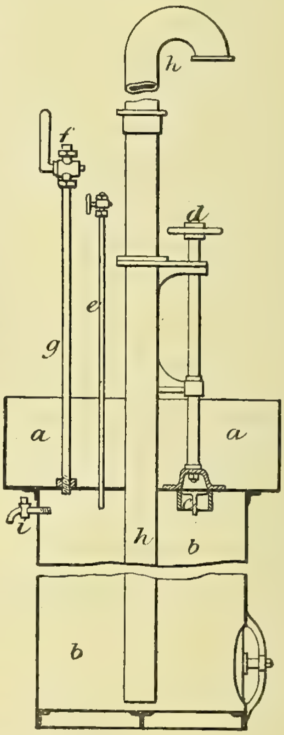
	FROM UNCHARCOALED JUICE.				FROM CHARCOALED JUICE. Using a dense char of 62 lb. per cub. ft., in proportion of about 0·6 times the weight of dry sugar obtained.		
	Masse-cuite.	Aska.	B.	⟨B⟩	*Masse-cuite.*	⟨B⟩	⟨A⟩
Sugar, crystallizable ..	76·000	95·500	99·500	99·600	80·000	99·500	99·100
„ uncrystallizable	12·740	2·650	0·230	0·240	11·920	0·210	0·470
Ash	1·507	0·306	0·103	0·036	1·917	0·067	0·072
Water	5·110	1·000	0·150	0·100	5·290	0·035	0·080
Unknown	4·643	0·544	0·017	0·024	0·873	0·188	0·278
	100·000	100·000	100·000	100·000	100·000	100·000	100·000

Aska is *masse-cuite* simply spun; B and ⟨B⟩ are made by washing the Aska in the centrifugals with about ½ gal. of water to 150 lb., and are marked according to grain and colour; ⟨A⟩ is of 1877 manufacture, and hence the comparatively large quantity of uncrystallizable sugar, produced by damp and heat during the long storage..

The system has been quite abandoned in Louisiana, after prolonged trial.

Pumps and Monte-jus.—As the apparatus by which the juice is extracted from the cane is generally situated on the ground floors of the building where the operations are conducted, it becomes necessary to adopt means for raising the juice into the vessels where it is to undergo purification and concentration. This is not the case in Louisiana, where the mill is usually placed at sufficient height to permit the juice to descend by its own gravity throughout the operations. Force-pumps, worked from the mill, possess many disadvantages, including limited capacity, churning of the liquid and consequent admixture of air, and contamination of the liquid with the grease used in their lubrication. They soon gave place to the *monte-jus* ("juice-raiser"), copied from the French. This is made in many different forms, one of which is shown in Fig. 1353. Its body consists of two chambers *a b*, separated by a steam-tight diaphragm; the upper chamber *a* receives the juice to be elevated while the charge in the lower chamber *b* is in course of elevation. When the lower chamber *b* is empty, the valve *c* is raised by turning the handle *d*, while the tap of the air-pipe *e* is opened. The juice contained in the upper chamber *a* immediately descends through the valve *c*, any air that may have been imprisoned in the chamber *b* escaping through the air-pipe *e*. This air-pipe extends about 6 in. into the lower chamber *b*, for the purpose of ascertaining when the chamber is sufficiently full, the escape of air through the pipe *e* being stopped as soon as the juice reaches its lower end. The cessation of the whistling noise made by the air rushing through the end of this pipe *e* constitutes the signal for screwing down the valve *c*, to prevent any further flow of juice into the lower chamber *b*. The air-tap is then closed, and the steam-tap *f* of the steam-pipe *g*, communicating with the boilers, is opened, when the empty space between the surface of the juice and the top of the lower chamber *b* fills with steam, which drives the juice out through the discharge-pipe *h*. As this pipe is carried down to within a short distance of the bottom of the *monte-jus*, nearly the whole of the contained liquor is forced out of the lower chamber *b*. As soon as any indications of steam appear at the mouth of the discharge-pipe, the steam-tap *f* is shut, and the valve *c* and air-tap *e* are opened to let in a fresh charge. It will thus be seen that the action of the *monte-jus* is exceedingly simple, only one precaution being necessary, viz. to shut the valve *c*, through which the juice is running, in time. If the juice be allowed to reach the top plate of the chamber *b*, the steam, when let in through the pipe *g*, will mix with and boil the juice, but will not elevate it; considerable difficulty and delay sometimes arise from this circumstance. As a precaution against carelessness, an overflow-tap *i* should be fitted to the shell of *b*, a few inches below the top, so that the superabundant juice might be drawn off. The juice, as it comes from the *monte-jus*, is sufficiently warmed to retard fermentation on its way to the clarifiers.

1353.



While this instrument remains by far the most generally adopted means of raising juice, it has been objected that its interior is not readily accessible, and that it is therefore difficult to keep clean, whereby fermentation may be caused in the juice. It is also urged that the liquor is diluted by the admixture of condensed steam. Hence, in many cases, the *monte-jus* has been replaced by centrifugal pumps. In favour of these, it is advanced that there are no valves nor other mechanism to become a refuge for dirt, no air nor steam is forced into the liquor, and, with properly adjusted arms, the juice is raised in a solid column without churning. Many statements, however, point to the fact that the churning is often seriously worse than with the *monte-jus*. In the best central factories, steam in the *monte-jus* is replaced by air under a pressure of 60 lb. a sq. in., thus obviating most of its drawbacks.

Defecation and Clarification.—Having, by any of the methods described, extracted as much as possible of the juice from the cane, the next operation is to eliminate from that juice all matters regarded as impurities from the sugar-maker's point of view, i. e. everything except the sugar and the water holding it in solution.

Preliminary Straining.—First of all, unless the juice has been extracted by diffusion, it is necessary to remove the gross impurities derived from the breaking-up of the canes. This may be done by a series of strainers, arranged so as to be easily removed, cleaned, and replaced. One of the best contrivances is a modification of the endless wire-web strainer, not essentially different from that on which the rag-pulp of paper-works is agitated and filtered from a great part of its water. The wire-gauze in common use has 40–60 threads per in., but it can be obtained of 80–90: the finer the better, provided the web presents a clean surface as fast as necessary. The strained juice is received in a shallow tray placed immediately under the horizontal part of the straining web, and passes thence by a gutter to the clarifier.

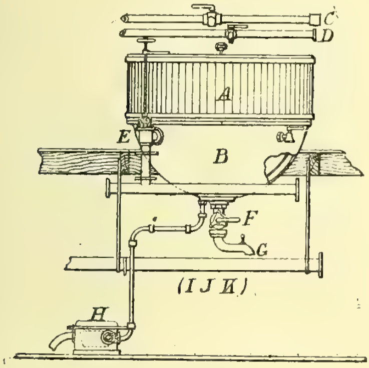
The chief means introduced for cleansing the juice are heat, chemicals, and filtration.

Heat.—Heat alone will exercise beneficial effect both by checking acidity—scalding the juice prevents acetous fermentation setting in, probably by destroying the fungoid germs which are its necessary accompaniment (presumably its cause); and by evaporating a portion of the acids holding the albuminous matters in solution, whereby the albumen is coagulated and rendered insoluble. It is also a valuable aid to the action of chemicals upon the juice, increasing the energy of the reactions set up, and thus greatly reducing the duration of the operation. Hence heat is now universally availed of in recognized processes of defecation and clarification. But if the heat is applied injudiciously, much of the crystallizable sugar is inverted.

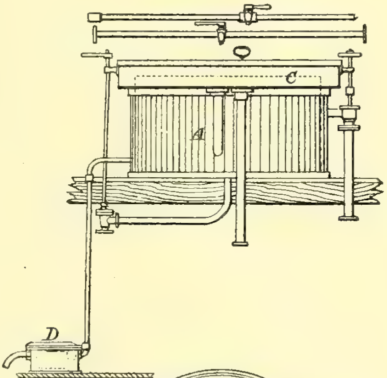
Steam Defecators and Clarifiers.—As the degree of heat employed is a matter of vital importance, it is most conveniently applied in the form of steam, that being readily controlled. Figs. 1354 and 1355 represent respectively an elevation and plan of a steam defecator made by Fawcett, Preston, & Co., Liverpool. The part B is composed of a copper, spherically-shaped lining, mounted in a cast-iron casing, to which high-pressure steam is admitted. The upper part A is a light curb of copper or iron to give capacity, and is clothed with lagging to prevent escape of heat. C D are pipes for juice and water; E is the steam-cock; F, the cock for drawing off the defecated contents; and G, a swivel-mouth pipe to direct the contents of the defecator as required into the clear-juice gutter, the turbid-juice gutter, and the washings-gutter. As the steam condenses in the double bottom of the defecator, the water flows away through the condense-water box H.

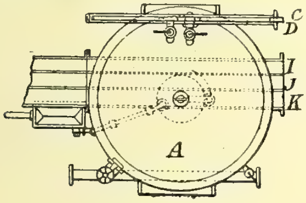
Lately many planters have adopted another system of defecating. Instead of providing 4, 8, or 12 separate defecators, with corresponding equipment of double bottoms, cocks, and pipes, they establish a powerful juice-heater, or vessel full of tubes fixed between two tube-plates. The steam is outside the tubes, and the juice from the mill traverses the space inside the tubes. If the mill gives 1500 gal. of juice per hour, a heater with 300 sq. ft. of surface will deliver the whole into say 3 empty tanks of 500 gal. each ; there the juice is defecated and left to subside. By using a juice-heater and 3 tanks, the same result is obtained as by a costly steam-boiler working at high pressure and 4 very costly defecators with their mountings.

1354.



1356.





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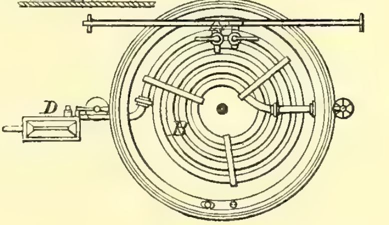


1357.

Figs. 1356 and 1357 represent elevation and plan of a steam clarifier and evaporator, made by Fawcett, Preston, & Co., Liverpool, which is used for treating the syrup after it leaves the triple-effect (see p. 1895). It is a cylindrical vessel provided with a steam-worm B fitted in the lower part; at the upper part, a border and gutter is formed, into which the scum is brushed as it rises on the syrup. The condensed steam in the shape of hot water passes through the box D, which has a float and cock to prevent uncondensed steam from passing uselessly away. The exterior A is lagged to economize steam by preventing the syrup from cooling. Every means must be adopted to save heat and fuel in a sugar factory, as it may be stated generally that 240 H.P. of steam are required to make a ton of sugar per hour, or 20 H.P. per hour for 12 hours; and in many sugar-producing countries, coal at the furnace-mouth costs 3*l.* a ton.

The use of the clarifier may be described in general terms as follows. The juice is raised to a temperature of 80° (176° F.), and sufficient milk of lime is added to neutralize the acid in the juice. The heat is then continued till a scum of impurities has risen to the surface, and commences to crack. The time occupied in this should be about 10–12 minutes from the commencement of the operation. The steam is then shut off, and the liquor is allowed to subside for 15–20 minutes, when the scum remains at the top; some heavy matter will have fallen to the bottom, and between them will be the clarified cane-juice, clear and of a pale straw-colour. The clarification being complete, the two-way cock is first turned on to the smaller aperture, until the top scum begins to appear; the cock is then turned to the large way, and the plug is taken out. The bottom sediment and top scum are conveyed to a cistern, whence they are placed in bags, and any juice remaining in is squeezed out, leaving only a small portion of solid matter behind.

Chemicals.—Of these, the most important and most widely used is slaked lime; following it come bisulphite of lime, sulphurous acid, lead acetate, and sundry special compounds, as well as antiseptics.

Lime.—The effects of heating are greatly augmented by the simultaneous application of a strong alkaline earth, such as lime, which combines with the liberated acids, and with any carbonates present, and thus forms an insoluble precipitate, which carries down much of the impurities. But any excess of lime beyond what is required to neutralize these acids will re-dissolve the coagulated albumen, and preserve it in a state of solution, until the excess of lime is again neutralized by addition of acid. The operation, which is called "tempering," is thus obviously one of extreme delicacy. The first point to ascertain is the exact amount of lime required by a given quantity of cane-juices. A bottle containing exactly 250 septems ($\frac{1}{40}$ gal.) is filled with filtered cane-juice of known sp. gr., and the juice is transferred to a beaker over a spirit-lamp, and stirred occasionally with a glass rod till it boils; after boiling for about a minute, clear saturated lime-water is poured in, a few drops at a time, till the juice shows a neutral reaction. The beaker is then taken off the lamp, and its contents are allowed to settle for a minute. If a coagulum of large flakes floats about in the transparent slightly-coloured liquid, and readily separates and subsides, the points of neutrality and of proper clarification coincide. The exact number of septems of lime-water used is then noted. If the floccules are small, and do not readily separate, the juice if boiled would throw up scum, and is not properly clarified. More lime-water is added till the indications of proper clarification are attained. The juice will now have a deeper tint than if excess of lime had not been required. The total number of septems of lime-water being noted, the calculation as to how much quick-lime is required for a given number of gallons of juice is:—If 250 septems of cane-juice required 20 septems of lime-water to render it neutral, and 10 more for clarification, then $30 \times 40 = 1200$, the number of septems of lime-water that 1 gal. of juice would have taken; saturated lime-water at the temperature common in tropical boiling-houses contains 0·00862618 gr. of quick-lime, therefore $1200 \times 0{\cdot}00862618 = 10{\cdot}351416$ gr. of quick-lime required by 1 gal. of juice. As a rough rule, the proportion of 1 septem of lime-water to 250 septems of cane-juice is nearly equal to $1\frac{1}{4}$ dr. of quick-lime to 100 gal. of juice. Hence the number of the test, multiplied by $1\frac{1}{4}$ dr. gives the weight in dr. of quick-lime required for 100 gal. of juice. This result is 1 per cent. too little. The test should be frequently repeated.

In the test, saturated lime-water is used, because it is easy to have it of uniform strength; but on the large scale, to use lime-water would entail great dilution of the juice, and waste of fuel in the subsequent evaporation. Hence "milk" or "cream" of lime is resorted to. The lime used must be thoroughly burned, quickly slaked with clean water (enough water being used to impart a creamy consistence), and carefully filtered through a very fine wire sieve, to remove all fragments of flint and unburnt and unslaked lime. The weight of these impurities removed must be deducted from the amount of quick-lime originally taken. Quick-lime can only be kept in perfect condition in closed vessels. The juice being tested as to its density and acidity, and the milk of lime being prepared, the twin process of defecation and clarification commences.

There are several ways of carrying it into operation. One of the most simple is that known as "cracking." It necessitates the use of two or more clarifiers, and is conducted as follows. The strained juice is admitted into the clarifier till sufficient has accumulated to prevent injury by heat. Fire is then made under the clarifier (or steam is admitted into the jacket or coil), and by the time it is full of liquor, the temperature will have risen to about 54° (130° F.). The "temper-lime" is then thoroughly incorporated, and the heating continued. A thick greenish-yellow scum appears on the surface, and increases in thickness, changing colour from exposure to the air; at about 79°–82° (174°–180° F.), numerous minute air-bubbles form a frothy layer under the thick scum, by and by forcing their way at a few points through the scum, which soon cracks, and shows the bubbles. The heat is then quickly withdrawn, and the contents of the clarifier are allowed to rest for 15–30 minutes or more. Ebullition is avoided, because it would break up the floating scum and diffuse it through the mass. The time allowed for settling depends on the nature of the juice and the proper apportioning of the lime. After settling, there is a layer of coagulum at top, and a precipitate at bottom, while the body of the liquor is bright and transparent, with a more or less deep sherry-tint, and minute flakes floating thick in it. If it is hazy, the heat has not been enough to clarify, or the lime has not been sufficient. After standing, the clear liquor is run off into the filter, and thence to the evaporating apparatus; the scum and sediment, with the considerable quantity of juice that invariably accompanies them, are usually run off to the skimmings-cistern, to be used in setting up liquor for rum (see p. 228).

When the clarifier has a steam-coil or -jacket, little loss of time occurs, for as soon as enough liquor is in the clarifier, steam is turned on so as to attain the desired temperature by the time the vessel is full. Fire-clarifiers are discharged by a stopcock near the bottom, till the liquor begins to run muddy; steam-clarifiers, by a valve in connection with a tube that rises 4–6 in. above the bottom, so as not to disturb the sediment.

This method is open to the objections that:—(1) Clarification is rarely attainable below the boiling-point of the juice, consequently the juice wants brilliancy and transparency, and minute floating particles render the filtration unsatisfactory; (2) the floating matter is thrown up as scum during the concentration, causing waste of juice in the skimmings.

Dr. Shier's modification is as follows:—The strained juice is boiled briskly for 5 minutes, the scum being constantly beaten down. While boiling, the proper quantity of temper-lime is added mixed with clay-batter, gypsum, or whiting-batter; the boiling, stirring, and beating down are continued for a few minutes. Neutralization being effected, the whole contents are rapidly withdrawn into a subsider, and left till the coagulated flocculent matter has subsided. The clear juice is drawn off and passed through a filter into a cistern. Here, excess of lime is corrected by careful addition of dilute sulphuric acid. It is safest to cease adding acid when the alkaline reaction becomes extremely feeble. Were the lime in excess, the sugar would be dark-coloured; were the acid in excess, the grain would be fine and soft, and part of the sugar would become uncrystallizable. The addition of heavy matter to the temper-lime causes the impurities to form a sediment which may be filtered off, instead of a scum which needs skimming. It is said to effect a great saving of juice. Clay-batter is prepared from stiff clay (containing as little sand and organic matter as possible), well dried, crushed to powder, and screened through a wire-gauze sieve of 10–14 threads per in. The sifted clay is mixed up with clean water to the consistency of cream or batter. About 4–8 gal. of this batter, mixed with the cream of lime, go to 500 gal. juice. Gypsum or whiting used in place of the clay must be in very fine powder.

Howard's process, strongly recommended by Wray, is as follows:—The juice is strained and gently warmed; for each 100 gal. of juice, 2 oz. of finely-sifted quick-lime, made into a cream with water, are added; the whole is well stirred, and heated to 82° (180° F.), until a thick crust forms on the surface, and shows a disposition to crack. This occupies 15–20 minutes after the addition of the lime; if it is very slow, the heat may be raised to 93° (200° F.), but not beyond. When the crust shows signs of cracking, the fire is stopped; the liquor is allowed to rest for 10 minutes, and drawn off through a fine strainer into a "precipitator." Here the firing is urged as high as possible without actual boiling, the rising scum being constantly skimmed off. The liquor is then boiled, continuing the skimming for 10–15 minutes, after which, the "finings" are well stirred in, and the boiling is prolonged for another 2–3 minutes, when the whole is thoroughly agitated, quickly run off into a subsiding-tank, and allowed to rest for 2–6 hours before passing through charcoal-filters into the evaporators.

The "finings" are thus prepared. Well-burnt lime is slaked with boiling water so as to form a cream; an equal bulk of water is added, and the mixture is boiled for some minutes, until the lime assumes the appearance of fine curd; the extraneous matter is then washed away, and the lime and liquor are run through a fine sieve. About 2½ lb. of alum for every cwt. of solid sugar (say 100 gal. of cane-liquor) is dissolved in 6 gal. of water, adding about 3 oz. of whiting (purified chalk) for each 2½ lb. of alum, the mixture being stirred until effervescence ceases. It is allowed to subside, and the solution (containing sulphate of potash, which is very injurious to sugar) is drawn off from the precipitated matters (alumina and sulphate of lime). After this, the precipitate is well shaken up with the prepared lime-curds, which are in such proportion that turmeric-paper barely changes colour by immersion in it, and recovers its yellowness when dry. The finings settle to the bottom of the vessels, and, after draining off the supernatant liquor, are placed on blanket-filters, until the mass contracts, and cracks on its surface; the finings are then fit for use. Cane-liquor is added in such proportion as will bring it to a creamy state, and then the whole is mixed equally into the liquor to be fined. The clarified cane-liquor remains for several hours before the bright liquor is drawn off. The object of the process is to procure sulphate of alumina free from potash and ammonia (see Alumina, p. 333). The alumina greatly assists the purifying action of the lime. (See Refining.)

Bisulphite of lime.—The bleaching and cleansing action of sulphurous acid led to experiment upon its applicability to the defecation of cane-juice, and the first form in which it was employed was as a compound with lime, known as bisulphite of lime. About 1 per cent. or less of solution of bisulphite is added to the juice immediately it is extracted, or even while it is being extracted. Heat is then applied, and after the juice has been boiled and stirred for a few minutes, a mixture of cream of lime and clay-batter is added. The exact quantity of cream of lime is ascertained by test (p. 1886), sufficient only being used to produce neutrality. After boiling for 5–10 minutes, and beating down the scum, the contents of the clarifier are run into a subsider, and thence filtered out for concentration. The subsidence is not efficient without the addition of some weighting matter; but the syrup has a very fine colour, and gives a superior-looking muscovado sugar. An objection is the high price of the bisulphite.

Sulphurous acid.—Next came the separate introduction of the lime and the sulphurous acid into the juice. This system has grown into very wide use in the United States, W. Indies, and other places. There are two principal ways of carrying it into effect:—(1) By first passing sulphurous acid gas into the juice, and then adding lime: known as Col. Stewart's process, patented in Louisiana and the W. Indies, and recently adopted in Egypt and elsewhere; (2) by first adding the lime, and then passing the sulphurous acid gas: Beanes' system, chiefly employed in Cuba, but also in Java and Australia. The effect is probably identical in both cases. The first-described plan is far the most common.

At Aba-el-Wakf, the following plan has been introduced. As fast as the raw-juice tank is filled, its contents are raised to the clarifiers, steam at 60 lb. being turned on as soon as the bottoms are covered. When the juice begins to boil, it is stirred with a copper pipe, through whose lower perforated end, sulphurous acid gas is injected, and allowed to dissolve in the juice, till the colour of the latter becomes considerably lighter, and a decided separation of the flocculent matter takes place. The quantity of sulphurous acid to be added varies: approximately, 450 gal. would require the combustion of $\frac{1}{10}$–$\frac{1}{2}$ lb. of sulphur. The sulphurous acid is forced into the juice by an iron pump (with indiarubber flap-valves), whose speed can be adjusted to the quantity required. The gas is generated by the combustion of crude sulphur in a cast-iron D-shaped muffle, the necessary air being sucked through by the pump; as the combustion depends on the air-supply, and the latter on the speed of the pump, the whole apparatus is self-adjusting. Some 50–60 ft. of 3-in. cast-iron cooling-pipe, with numerous holes for removing "flowers" as formed, conduct the gas to the tanks.

As soon as the boiling juice is sufficiently "gased," milk of lime mixed with China-clay is added at the rate of $\frac{1}{2}$–3 gal. per 450 gal. of juice, till it is perfectly neutral; it is then let into subsiders to stand till the impurities have settled. The use of sulphurous acid necessitates the employment of about 4 per cent. additional lime. The combination of sulphurous acid and lime permits the production of a grey-white muscovado ("grocery") sugar.

Other Alkaline Earths.—It has been proposed to replace lime in defecation by other alkaline earths, such as barium and strontium. Their effect is more powerful than that of lime, but they have not come into general use on account of the prejudice regarding their poisonous qualities, and the risk of some being left suspended in the sugar. As regards barium, there is no proof of its deleterious qualities when present in such quantities as are found in sugar treated with it; but an expert can at once detect the use of any barium salt, by the modified form of the sugar-crystals, which modification shows that barium salts are still present, and hinders the sale of such products.

Lime sucrate.—This process is described under Refining.

Lead acetate.—Many years ago Dr. Scoffern employed the subacetate of lead ("sugar of lead") as a defecating agent, and many inventors have since improved on his method of manipulation. This carries down many of the impurities as a precipitate, leaving sugar in solution, and any possible excess of the lead salt is thrown down as insoluble sulphite by the injection of sulphurous acid. Sugar was prepared by this process, without any injury resulting, but an outcry against the poisonous nature of lead acetate, and the dread that some might be accidentally left in the sugar, caused the process to be officially condemned. Lead certainly was present in the sugar, but it is not known whether it was in a poisonous form or not.

Sulphur and Chlorine compounds.—One of the most recent innovations in defecating is the invention of Eastes, Lukin, and Boyd, of Brisbane, and known as "Eastes' process." The juice may be tempered and clarified either hot or cold, but the liquor must be heated to boiling-point to coagulate all the albumen. When the juice is in the clarifier, 4–8 oz. of chloride of sulphur are added to each 100 gal. of juice, according to the supposed quantity of albuminous matter present, the necessary quantity first being mixed thoroughly with a small quantity of the juice in a small vessel, and then gradually poured into the clarifier, whilst the liquor is agitated. In addition to the chloride of sulphur, in the case of juice containing free acid, sufficient lime must be used to neutralize it. Sulphide of lime and "chloralum" (chloride of aluminium) may replace the chloride of sulphur. After the application of the particular chemical selected, the liquor is brought to boiling-point, and allowed to rest for not less than 45 minutes, by which time the precipitate will subside, and a perfectly clear liquor remain. This is then run off to be evaporated.

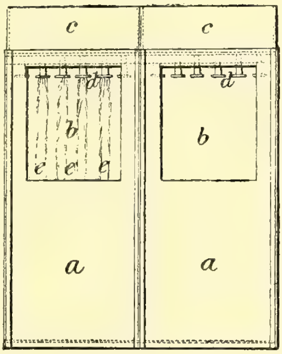
Sulphur, Lime, and Charcoal.—John McGregor, of Tobago and Trinidad, has recently introduced a plan called the "arvation" process. It consists in burning sulphur, lime, and charcoal in a furnace, and conducting the fumes into the liquor; its advantages are nil.

Yellow Crystals.—The beautiful Demerara "yellow crystals" owe much of their brilliant colour and transparency to delicacy of tempering. The temper used is lime-water rather than cream of lime, the density being only 10° instead of 17° B., and preference is given to rain over trench-water. The clarifier is filled with sulphured juice, tested repeatedly, while it is entering and while lime is being added, to ascertain the exact quantity of lime necessary: when it is known, the whole quantity is for the future introduced before the clarifier is one-quarter full.

The exact proportion of temper is decided (1) by the neutral reaction on test-paper, and (2) by the appearance of the limed and agitated juice when filled into a foot-glass placed in the light and allowed to subside for 5 minutes. The appearance wished for is brilliant transparency combined with a golden colour. The right quantity of lime is that which will give this result, though the liquor may be a trifle alkaline. With inferior juice, colour must be sacrificed for transparency, and lime added till transparency is attained, even though the colour be intensified to light-red. Too light a colour, which is sometimes compatible with good transparency in the case of superior juice, will result in a green-coloured sugar. Over-tempering causes the sugar to turn greyish-brown when cured. For the subsequent treatment of the liquor in the vacuum-pan, see pp. 1894–5.

Filtration.—Filtration of the juice is a necessary adjunct to the defecation by heat and chemicals, its object being the removal of the matters rendered insoluble by these operations. The chief kinds used are bag-, charcoal-, and capillary filters.

1358



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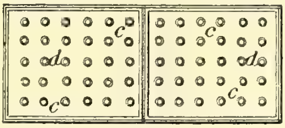

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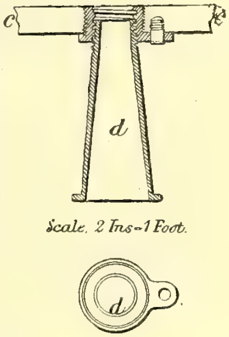

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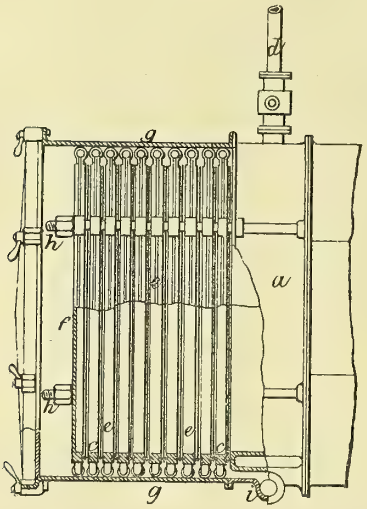
Bag-filters.—The construction and arrangement of these are shown in Figs. 1358 and 1359. The filter consists of a wrought-iron case *a*, with openings at *b*, and an internal flange at top to carry a cast-iron box *c*, having holes in the bottom, for the reception of gun-metal bells *d*, to which are attached the cotton-twill filter-bags *e*. Fig. 1360 shows an enlarged section of the gun-metal bell *d*. The bags *e* fastened to these bells are 3–6 ft. circ. and 6–10 ft. long, woven without a seam. They are crumpled up inside "sheaths" of strong open webbing, about 18 in. circ., which restrict their expansion. They are arranged in series of 100 or more.

Charcoal-filters.—These are large, slightly tapering, cylindrical vessels, generally of wrought iron, with a perforated false bottom about 1½ in. from the bottom. A blanket covers this false bottom, to prevent the charcoal from being carried through with the liquor. Some charcoal, however, always accompanies the first liquor, which is caught in a separate receiver, to be filtered over again. In filling these vessels, the first few inches of charcoal should be pressed compactly down, after which, it is packed lightly but evenly as near to the top as will leave a convenient space for the liquor. The object of these filters is to remove the vegetable colouring matter from the liquor, together with the fine suspended impurities that have escaped the bag-filters. Use is made of both animal charcoal (bone-black) and wood charcoal, but the former is in most general favour. (See also Beet-sugar, pp. 1851–4; Refining.)

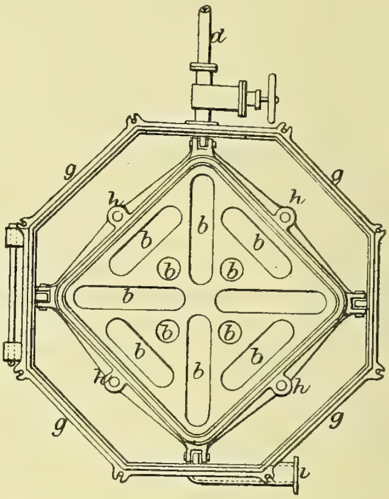
Capillary filters.—A representative filter of this class is that invented by F. A. Bonnefin, of Guadeloupe, and made by Corcoran & Witt, 30 Mark Lane, London. It is intended to be used in conjunction with his "continuous preparator" (see p. 1898), which effects the removal of the coarser impurities prior to the tempered juice entering the filter proper. This latter separates solid matters from liquid by capillary action taking place through fibres held between surfaces of a yielding material, and aided by pressure or suction. The bundles of fibres are usually, for convenience, woven into an exceedingly loose fabric, preferably of pure cotton. At one end, they are in contact with the mixture to be filtered; the capillary action of the fibres draws the clear liquid past the yielding surface, whilst the solid matters are left behind.

Figs. 1361–2 show an elevation partly in section, and a transverse section of one way of arranging the filter. The apparatus consists of a central chamber *a*, to which the material to be treated is supplied by a pipe *d*, pressure being obtained by a pump, or by allowing the material to descend from an elevated cistern. The two sides of the chamber *a* are slotted, as shown at *b*, to allow the free escape of the material on either side. The two faces of the chamber *a* are also grooved all round, and the grooves are filled with soft indiarubber *c*, so as to project above the face of the chamber *a*. Against the face, is placed the filtering fabric, of such a size as to overlap the indiarubber all around; holes are cut in it, corresponding to the slots *b*. Against the fabric, is placed a rectangular brass frame *e*, grooved and fitted with indiarubber in the same way as the faces of the chamber *a*. Another fabric is placed next, then another frame, and so on in succession. The alternating series of brass frames, filter-cloths, and indiarubber terminates in a cover-plate *f*.

1361.



1362.



The bolts *h*, fixed to the chamber *a*, hold the filter together. The outlet is at *i*. The material is admitted to the filter throughout its whole length by a gutter leading from the feed-pipe. Filtration takes place, not through the fabric, which is woven so loosely as to be transparent, but from its edges, the pure liquid traversing the fibres longitudinally till it escapes at the margin, while the solid matters are arrested, and range themselves concentrically upon the fabric around the indiarubber surface. A filter with plates 15 in. diam. and containing about 30 duplicate surfaces of fabric, will pass 120 gal. per hour. The dirty fabrics need only a few minutes' rinsing in hot water to cleanse them from the adherent solids, and are at once ready for re-use. The action of the filter is purely mechanical, and it is not capable of removing impurities in chemical combination or solution.

Galvanism.—W. Eathorne Gill, of London, proposes a system of defecating by galvanism in conjunction with chemical agents and filtration. Galvanic and chemical actions are set up by the use of zinc strainers and strips, coated with a composition whose base is clean grease, the other ingredients consisting of charcoal, metallic sulphides, silica, alumina, and any insoluble lime salt, reduced to powder, and intimately blended. A zinc strainer receives the juice, which escapes by the orifices into a surrounding separator, where the lighter impurities rise, while the heavier pass into a bed of clean sand. It is claimed that the combined effect of the composition and the galvanic action set up in the juice is complete defecation, and prevention of all fermentation. But the only efficient part seems to be the sand-filter, which has long been known and appreciated.

CONCENTRATION AND GRANULATION.—The cane-juice, reduced to the condition of a clear solution of sugar (with some few salts as impurities) in water, has next to be deprived of so much of its water as will permit the sugar to assume a solid (usually crystalline) form. This operation, termed "concentration" and "granulation," has been described in principle on p. 1854. The inversion of sugar during concentration of cane-syrup is said to be prevented by the introduction of superphosphate of lime into the juice before boiling. There is no evidence as to the practical utility of this plan; but phosphoric acid appears rather to aid the crystallization of sugar (see p. 1850), and the process would therefore seem to be based on good ground. Both heat and cold have been applied to the concentration of cane-syrup, but chiefly the former.

Heat.—The means by which heat is applied to the evaporation of cane-juice may be described under five separate heads, according to their principles:—(*a*) Pans heated by fire, (*b*) pans heated by steam, (*c*) film evaporators, (*d*) vacuum-pans, (*e*) bath evaporators, (*f*) Fryer's concretor.

a. Pans heated by Fire.—The earliest and crudest system of evaporation was the "copper-wall," or "battery" of open pans called "teaches" (taches, tayches, &c.) The first two pans of the series are the clarifiers; thence the juice flows into the teaches, sheet-copper pans set in masonry on a descending plane. As the juice concentrates, each lower pan fills up with liquor from the one immediately above it, until the density of the liquor in the "striking-teach" permits granulation, when the mass is ladled into shallow wooden vessels, and conveyed away to be "cured." By the oldest method, the liquor was ladled throughout the series. More recently an improvement was introduced, consisting of a copper dipper, fitting inside the striking-teach, and having at the bottom a large valve, opening upwards and worked by a lever. The dipper is attached to a crane, which commands the striking-teach and the gutter leading to the coolers. This greatly economises time. The furnace for heating the series is set under the striking-teach; the heat passes by flues to the chimney or to the boiler-flue.

In working a battery, the difficulty is determining the exact moment when the boiling of the "sling" in the striking-teach must cease, i.e., when to make a "skip;" great skill and experience are required to suit each kind of juice. The main point is to bring about crystallization in the sling in as great mass as possible after it cools: if the sling be taken out too soon, there will be only a few large irregular crystals, and a quantity of sugar will be left in the molasses; if the sling be boiled too long, a sticky mass of tiny crystals and syrup will result, from which the molasses can only be drained off with great difficulty, and from which it is impossible to obtain clean, dry, and hard crystals. An experienced "wall-man" knows the approach of the striking-point; but a good test is the following:—Pour a spoonful of the boiling sling into a glass of clear water; if, after a minute's cooling, the sling can be formed into a ball which does not stick to the fingers, and slightly flattens itself on the bottom of the glass on being dropped in, the correct period has arrived for striking.

The continued use of the copper-wall is an illustration of the backwardness of the cane-sugar industry in many places. Its drawbacks are:—(1) Waste of fuel; (2) the amount of labour required and length of time occupied; (3) considerable waste of liquor in the sloppy manipulation; (4) the proportion of molasses produced is intensified by the churning-up of the liquor and consequent admixture of air, and by the irregular and uncontrollable action of the heat upon the surface of the metal with which the liquor is in contact. The temperature prevailing in the striking-teach is not less than 110°–113° (230°–235° F.) in any part, and much greater at the bottom of the mass. It is therefore not surprising that liquor showing 10 per cent. of inverted (uncrystallizable) sugar in the first pan, should have 22–23 per cent. by the time it is finished in the striking-teach.

b. Pans heated by Steam.—The simplest form of steam evaporating-pan consists of a rectangular wrought-iron tank, at the bottom of which is a series of copper steam-pipes, connected by gun-metal bands brazed to them, and carried on wrought-iron supports. The tank is fitted at the side with a steam-valve at one end of the steam-pipe range; at the other side, is a cast-iron box, fitted with a wrought-iron pipe, for the escape of the condense-water to a condense-box. This form of evaporator presents a large heating surface, with facility for cleaning. By passing the ends of the steam-pipe range through stuffing-boxes, the pipes can be turned up, and all parts of the interior of the tank be readily cleaned, a matter of great importance.

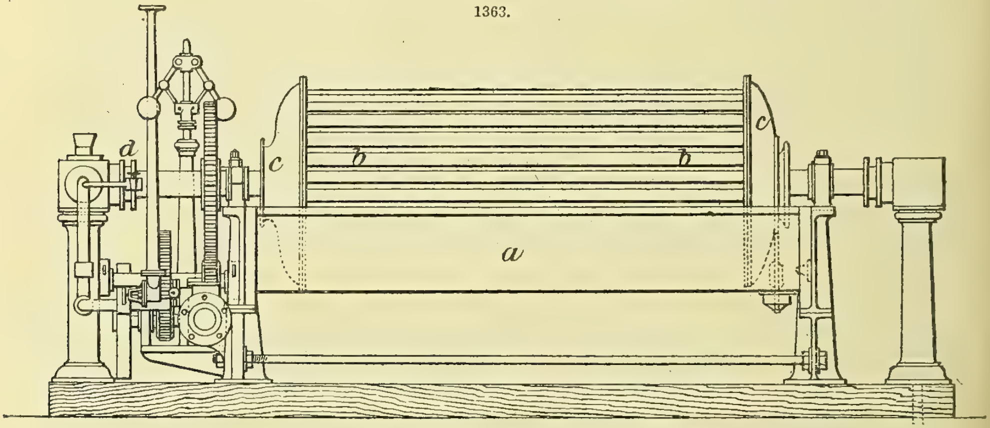
Under Pressure.—The 5 steam concentrating-pans erected at Aba-el-Wakf receive the juice when it has fallen to a temperature of about 71° (160° F.) Each consists of a copper tray, 23 ft. long and 6 ft. wide, heated by a steam-boiler beneath, and covered by a sheet-iron casing which confines the steam evolved from the juice. The steam-boilers work under 60 lb. pressure. The heating surface of each tray is increased by 495 vertical nozzles screwed into it; these are of brass, cast very thin, and slightly tapered. Their mean external diameter is 2⅛ in., and they project 4½ in. above the plate. If the juice is in good order, it makes very little foam; if not properly tempered, a thick froth soon forms, but appears to condense against the cover, and drop back into the boiling fluid. Each particle of juice takes about 18 minutes to pass through the tray, and though exposed to the temperature due to 3–4 lb. pressure of steam on its surface, the syrup gains hardly more colour than would be due to the increased density. The steam generated from the juice is collected into a wrought-iron main, and taken by one branch to the vacuum-pans, and by another to the vacuum-pumps and centrifugal-engines, which it actuates, supplying all the power necessary for boiling to grain, curing, and raising the water required throughout the mill. A great drawback to the use of steam from the juice is its low pressure (3–6 lb.).

The advisability of concentrating syrup under pressure in this manner has been the subject of much discussion. It is usually held that any temperature above 60° (140° F.) is prejudicial to sugar solutions, and that above 74°–77° (165°–170° F.) the proportion of sugar inverted to the uncrystallizable condition is very large. A perfectly white refined sugar exposed to a temperature of 107° (224° F.) for 3 hours becomes quite yellow. The normal boiling-point of syrup at 10° B. is about 101° (214° F.). In these pans, the extra pressure of 3–6 lb. of steam means an increase of 8°–16° F. in the temperature in order to arrive at the boiilng-point, which would seem to be highly injurious. Long exposure, however, is quite as mischievous as high temperature. It is easy to avoid one by incurring the other; the difficulty is to avoid both. Perhaps the chief harm of rapid concentration at a high temperature is the violent ebullition of the mass, whereby portions of heated surface are momentarily left dry. The Aba pans, working with a steam temperature of 143° (290° F.) on the under side, and the juice being at $105\frac{1}{2}°$ (222° F.), actually made less molasses (i. e. inverted and charred sugar) than some more generally-recognized plans. Still the system cannot be recommended for adoption where there is no necessity for using the water evaporated from the juice.

c. Film Evaporators.—Under this head are particularly included those evaporators which depend upon the principle of exposing thin films of liquid to the action of a heated surface in the open air. They are generically known as "wetzels" among planters, and comprise the "pans" bearing the names of Gadsden, Wetzel, Schroeder, and Bour, and many modifications, some of which, such as Murdock's, have steam-heated coils. The original form was Aitchison's simple cylinder revolving with partial immersion in the liquid, and heated internally by steam. In its revolution, the cylinder carries on its surface a film of liquor, whose water is soon evaporated. In the Gadsden pan, the cylinder is replaced by a skeleton cylinder, consisting of two metallic discs connected by a series of metallic rods fixed at short intervals around the periphery of each disc. Here the drawbacks are the churning of the liquor (except at very low speeds), and the insufficiency of the heat derived from the steam-jacket of the pan.

Wetzel's improvement upon this is the substitution of steam-pipes for the solid rods. This overcomes the deficiency of heat, and has been very generally adopted, though the churning is not reduced. Fig. 1363 shows the Wetzel pan and its special engine, as made by Fawcett, Preston, & Co., Liverpool. The pan *a* contains the liquor; the pipes *b* are heated by steam passing through them; and the whole cylinder *c* is caused to revolve by the engine *d*. The large heating surface enables steam at very low pressure to be used, exhaust-steam from the cane-mill engine being sometimes utilized for the purpose. By fitting the pipes diagonally (instead of horizontally) between the discs, the churning is modified, but not altogether prevented. The greater exposure to the air also causes increased oxidation of the juice and inversion of the sugar.

1363.



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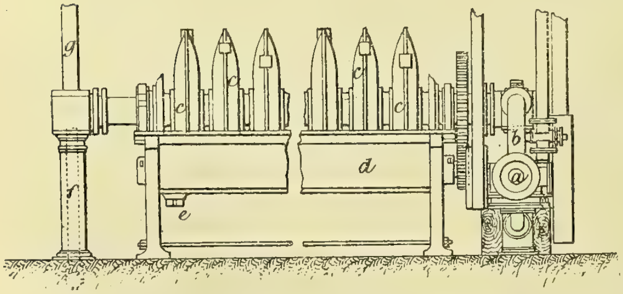

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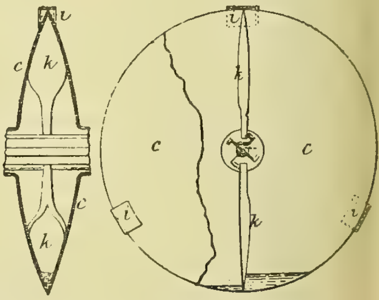
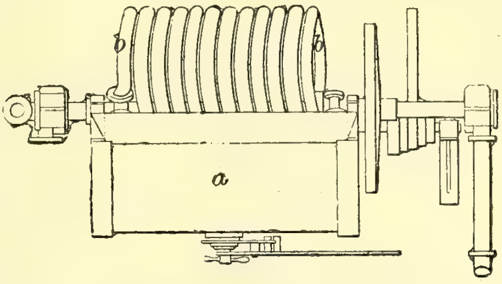


Schroeder overcomes the churning by having a jacketed pan fitted with a set of revolving solid metallic discs strung upon a square shaft, and fixed about 6 in. apart. The apparatus has the additional advantage of cheapness, but the heat derived from the steam-jacket requires to be supplemented by a coil of steam-pipe winding between the discs, which constitutes an evil.

Bour, observing that larger grains of sugar are produced on the discs in Wetzel's pan than on the pipes, concluded that hollow steam-heated discs would increase the evaporating surface, and produce better grain. A front elevation of his pan is shown in Fig. 1364; and vertical and transverse sections of the disc on an enlarged scale in Fig. 1365. *a*, is the steam-engine; *b*, exhaust-pipe to heat the revolver; *c*, revolver consisting of 10 copper discs; *d*, copper pan for holding the liquor under treatment, and discharged by the valve *e* at bottom; *f*, pipe for carrying off the condensed water from pan; *g*, pipe for carrying off air and uncondensed steam; *h*, safety-valve. The discs are mounted on an axis which allows the steam to communicate freely with them, at the same time collecting the condense-water and carrying it off at one end. Inside each disc are 2 spoons *k*, running from the extreme diameter and terminating in the axis, into which the water is delivered. Outside the discs *c*, are small buckets *i*, which lift the liquor as the discs move round, and spread it as a thin film over the surface which is not immersed. The speed of the revolver is 10–20 rev. per minute. Where steam is plentiful, equally good sugar is produced by the quicker speed, and nearly double the work is performed in the same time. One pan cooks 12 cwt. of sugar per hour, from 20° B., as taken from the battery, the temperature never exceeding 77° (170° F.). The distributing-cups churn the liquor excessively.

1366.



One of the most recent modifications is Pontifex's, shown in Fig. 1366. The pan *a* contains the liquor to be evaporated, within which revolves a coil of steam-pipe *b*. Thus a large heating-surface is obtained, without the drawback of churning up the liquor.

It is to be observed that all these forms of film evaporator are destined only to finish the concentration begun in the battery. The liquor is brought to them at a density of 26°–27° B.

d. Vacuum-pans.—The principles controlling the boiling of juices *in vacuo*, and the details of the construction of vacuum-pans and their accessories, have been already given under Beet-sugar (see pp. 1856–7).

Figs. 1367–1370 show vacuum-pans as used on nearly all large sugar plantations. The grain formed from syrups boiled *in vacuo* is larger and more solid than that from syrups simply concentrated to crystallizing-point in open batteries. A Cuban hogshead will contain only 1600 lb. of sugar made in a copper-wall, but 1800 lb. of vacuum-pan sugar. By the use of the vacuum-pan also, the planter is enabled to boil his molasses, and to extract from 1 gal. some 4–5 lb. of sugar, still having a second molasses for the distillery.

Working the Vacuum-pan.—The air-pump is started, and so soon as the vacuum reaches 26–27 in., the feed-cock on the side of the pan is opened, and sufficient liquor is drawn in to completely cover the first coil; steam is next turned in, and the liquor rapidly concentrates; fresh supplies are admitted at short intervals, the feed-cock being opened say for 15 seconds at a time, until the mass commences to show "grain." The grain is fed carefully, the cock being opened frequently, and each time the quantity admitted is increased. As the amount of sugar in the pan continues to augment, steam is turned into the 2nd and 3rd coils, until, at the completion of the charge, the pan is nearly full, or just below the sight-glass. In this way, the grain "grows" in size. On the conclusion of the boiling, the vacuum is destroyed, and the charge is run out into a tank, and allowed to stand for an hour or two, when a further crystallization takes place.

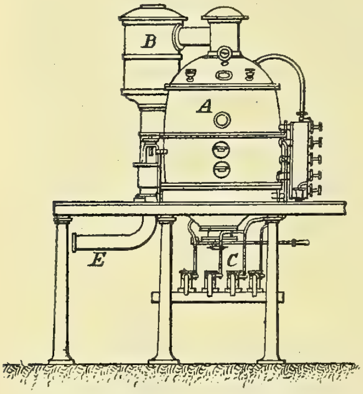
It is customary to draw in as much syrup as will cover the bottom coil (when reduced by concentration), called "graining low down." Some prefer to grain higher; some when the pan is half-full. An objection to graining high is that the grain has not so much time to grow, but it does not always hold good. A pan taking 7 hours to boil a strike of 8 tons of *masse-cuite* (concentrated juice) grained low, will only take 6 hours if grained higher. The crystals in the second case will not be so large, but, in an 8-ton pan, they will be of fair size, even by the quicker method. The drawing-in is conducted thus:—The charging-cock is opened, and shut off again as soon as the liquid boils up to the "bull's-eye" on the opposite side. The contents quickly boil down; the cock is opened again, and shut off as before when the liquor boils to the same height. This is kept on until the syrup intended to form grain has been taken in: roughly speaking, 2000 gal. of good 18°–20° B. syrup to a 5-ton pan is about the correct amount.

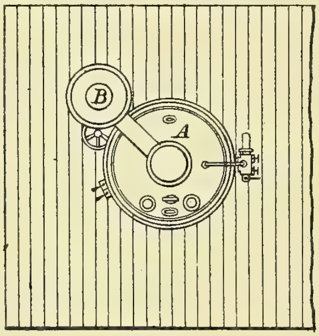
The granulating-point is easily recognised by a practical pan-boiler: a "proof" of the syrup, taken between the thumb and finger, should draw to a thread $\frac{3}{4}$-in. long; but this test is of no value if the syrup is sticky, resulting from under-tempering or sour canes.

In boiling for large grain, it is essential to grain low. The grain commences to form in minute specks; these rapidly increase in number and size, until the whole mass of liquor is filled with them. As each lot of syrup is admitted, it deposits on the grains already formed, causing these to grow larger. During granulation, the temperature should never be more than 71°–78° (160°–172° F.), though raised later on to harden the crystals; but this must not be done too soon after graining, or the crystals will melt.

Rules for graining syrup in the vacuum-pan are:—The thinner the syrup admitted, the bigger will the crystals be; for large-grain sugar, few and heavy charges must be admitted, so as to give the grain time to grow; the larger the crystals are required, the more quietly and slowly must the boiling be carried on; to make regular grain, granulation is brought about very slowly, and on no account must the grain be forced by boiling very high before the first charge.

1367.





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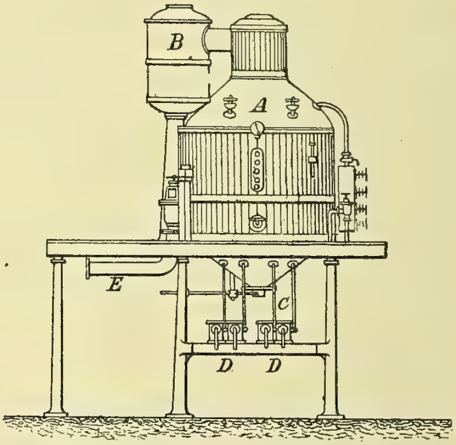
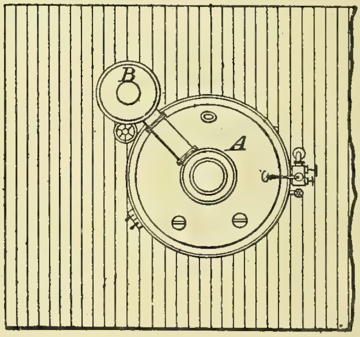
1369.





1370.

It is important in pan boiling to avoid forming "false grain." The two stages when the danger of it is greatest are:—(1) The time when the sulphuric acid (for producing "yellow crystals") is admitted into the pan; (2) the "opening" of the sugar when re-starting the pan to "double," i. e. when, having struck out half the contents of the pan, fresh portions of syrup are admitted on to the *masse-cuite* left in the pan. If the contents are not sufficiently high when sulphuric acid is admitted, false grain forms whilst working up for striking. Unless the *masse-cuite* be "opened" very slowly, the new lot of syrup, instead of depositing on the already-formed crystals and increasing their size, will form an independent grain, called "false grain," which not only spoils the sugar, but prevents the molasses leaving it in the centrifugals.

When false grain is very bad, the best course is to strike it out immediately, and spin it in the centrifugals, mixing it with warm water if absolutely necessary. When not very bad, and the pan is little more than half-full, the heat and washing of a few heavy charges of new syrup will remove it.

Demerara "yellow crystals."—Sulphuric acid imparts to the sugar the delicate yellow bloom so much admired in "Demerara crystals," instead of the ordinary green-grey colour. If too little is mixed with the *masse-cuite* in the pan, the colour is scarcely improved; if too much, the sugar turns quite red a day or two after curing. It is admitted last of all; pan-boilers should not be allowed to make a charge of syrup on to it immediately previous to striking. The quantity of acid to be used depends on the colour of the *masse-cuite*; as a rule, 3 gal. of acid diluted with 1½ gal. of cold condensed water to 5 tons of sugar is about right. In all cases, the least possible quantity should be used compatible with securing the desired result.

The proper striking-point is of great importance, and arrives when the proof will scarcely run out of the socket of the proof-stick. *Masse-cuite* on leaving the pan should have a light-red colour tinged with gold, and a temperature of 66° (150° F.)—never higher. The objects of doubling are to increase the size of the grain, so that the market value of the sugar may be enhanced, and to save time. Some syrup makes sugar that will bear doubling 2–5 times; while some gets sticky after the 1st cut of the pan. Great care must be taken while opening the *masse-cuite* left in the pans; for the 3rd or 4th cuts, a temperature of 74° (165° F.) may be maintained while opening slowly and carefully, the operation requiring 15–25 minutes. The drawing-in of syrup demands more care in subsequent cuts than in the first.

Great loss of sugar is caused by doubling, depending on the amount of acid used, and on the quality of the syrup; it is estimated to amount to 20–25 per cent. of the sugar, and some hold that a better return is obtained from the larger quantity of dark sugar at a lower price; but on the other hand the "loss" means sugar converted into a high class "golden syrup," and the extra market value of the yellow crystals is affirmed by some of the best authorities to more than atone for the extra cost and increased inversion of crystallizable sugar.

When sour canes are sent to the buildings, the sugar is apt to get sticky in the pan, and occasionally to such a degree as to interfere with the formation of grain, and endanger the whole strike of sugar. If the stickiness is not very bad, 2–3 buckets of strong lime-water, taken into the pan through the acid-cock, will put things straight. Besides this, the excess of acidity should be neutralized by lime-water, leaving the syrup only slightly acid before drawing into the pan.

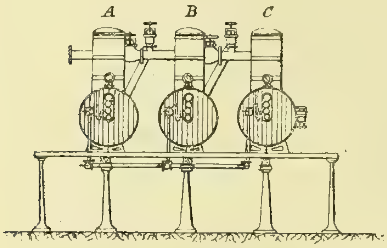
Molasses.—"First molasses" runs from *masse-cuite* which has had no molasses boiled into it; "2nd molasses" drains from *masse-cuite* boiled with molasses in it; "3rd molasses" drains from vacuum-pan molasses-sugar (not muscovado sugar). These are kept distinct. Third molasses is so sticky and impure that it is sent to the rum distillery (see Alcoholic Liquors—Rum, p. 228), as is also sometimes the case with 2nd molasses, when low quotations do not pay to convert it into sugar. Only 1st molasses should be used for mixing with syrup-sugar in the pan, and 2nd molasses for boiling molasses-sugar ("3rd sugar"); 2nd molasses should never be used for boiling with pure syrup-sugar in lieu of 1st molasses. There is a great difference of opinion about the boiling of molasses; but the plan now to be described is the best, provided arrangements permit the molasses to be boiled within 1–2 hours of separation in the centrifugals.

Supposing that the pan has struck out 3 tons, been refilled and cut a second time, leaving it still half-full, for a third time fresh molasses tempered with lime-water, and reduced with water to 30° B., is drawn in. The contents, struck out and "spun" in the centrifugal, should yield 2½–3 tons of 2nd sugar, i. e. syrup-sugar with which molasses has been boiled, giving about 1·2 tons of sugar from molasses, much improved in colour, in addition to the 2 tons obtained from the syrup, and upon which the molasses was admitted. To make a very pale sugar, this process will not answer, and the molasses must be made into fine quality 3rd sugar, or into rum.

For tempering molasses, lime-water should be stirred in until most of the acidity is destroyed, and only a faintly acid reaction is shown on litmus-paper. For 2nd and 3rd syrups, or molasses which is to be boiled for grain, the density must be reduced to 30° B., either by blowing in live steam, or, if this be inadmissible, by the addition of condensed water. The boiling is performed in an exactly similar way to 1st syrup, except that it is useless to try for large grain, as the impurities effectually prevent the grain from increasing beyond a certain size. It is not an unusual custom to considerably raise the temperature before striking, by dropping the vacuum 2–3 in.; this is readily done by checking the supply of water to the condenser, and keeping the steam full on the coils and jacket. The temperature of the *masse-cuite* is then about 77° (170° F.), whereas it has previously been about 68°–74° (155°–165° F.). The object of this is to harden the grain, in order that it may be washed in the centrifugal. The *masse-cuites* from 2nd and 3rd syrups should always be allowed to stand 2–3 days in coolers, to "grow" the crystals before centrifugaling. Molasses from 3rd sugar of about 34°–36° B., are always "jellied" or "boiled smooth," and it is not then necessary to reduce the density. If very acid, they should be nearly neutralized, and boiled until a proof will draw out in a thread 1–1½ in. long between the finger and thumb. At this stage, and before any sign of granulation has commenced, the contents of the pan are discharged into a cooler, and allowed to stand for 1–2 weeks, until the sugar has properly granulated, before centrifugaling.

Multiple-effects.—Figs. 1371, 1372 show an elevation and plan of a set of horizontal triple-effect apparatus by Fawcett, Preston, & Co.; and Figs. 1373, 1374, an elevation and plan of a set of vertical triple-effect apparatus by the same firm. This apparatus enables the planter to make use of all the exhaust-steam that can be collected in the sugar-house, gives a syrup in good crystallizable condition, and saves labour. It also permits the use of a vacuum-pan in many places, where with a double-effect or a simple evaporating-pan it would be impossible, on account of scarcity of water. The exhaust-steam enters the heating-space of the pan C, and is condensed by the juice contained in the tubes. The first pan C is therefore a surface-condenser, and requires no

1371.



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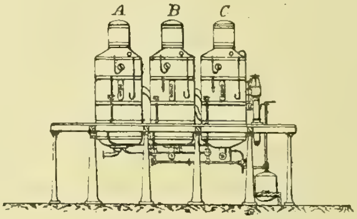

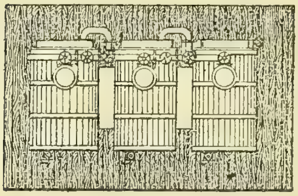

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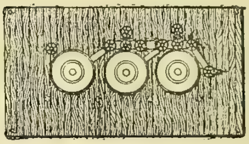


1374.

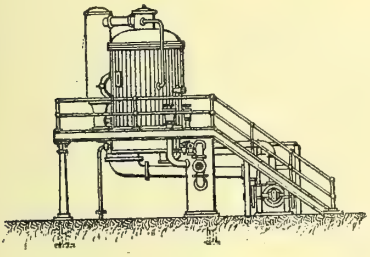
injection-water; and the condensed water runs away to a receptacle, to be used again in the boilers. The vapour from the juice in C passes into the interior of B, producing a second ebullition, and is condensed here again by surface-condensation. The condensed water from this pan is water of vegetation, as it comes from the cane-juice; it is taken for washing the animal black. Finally, the vapour from B enters A, and the vapour formed in A is condensed by direct injection. As, therefore, injection-water is only used for condensing the vapour formed in the pan A, great economy is obtained. Triple-effects can be constructed either of vertical or of horizontal vacuum-pans. Each system has its advantages, but when equally well constructed and worked there is little or no difference in their results. On the whole, it may be said that the horizontal system does not require such expensive machinery and such good execution as the vertical.

The saving in labour secured by the employment of triple-effect apparatus may be conveniently illustrated by some actual figures obtained on two similar estates, with syrup and sugar of identical quality and value, and under equally able management. On the estate using open batteries and a single vacuum-pan, the labour (negro) was as follows:—17 hands at centrifugals, 25 at batteries, 4 at vacuum-pan and engine, 8 collecting fuel, 4 at steam-boiler: total, 58, working 18 hours a day = 1044 hours of labour. The second used a juice-heater, defecating- and subsiding-tanks, a triple-effect, and a vacuum-pan, and employed the following labour:—12 hands at centrifugals, 3 at triple-effect, 2 at vacuum-pan, 4 collecting fuel, 6 at steam-boiler, 3 engineers, 4 at defecators, 2 at scum-tanks, 2 at syrup-tanks, 2 at molasses-tanks; total, 40, working 13 hours a day = 520 hours of labour. Each factory turned out 13 tons of 1st and 2nd sugars per diem.

Figs. 1375–1378 show an arrangement by Manlove, Alliott, Fryer, & Co. In each pan, is a vacuum above the boiling liquor—slight in the 1st, better in the 2nd, and very complete in the 3rd. This is attained by a vacuum-pump, driven direct by a steam-engine, and similar to the vacuum-pump of an ordinary vacuum-pan. The flow of the liquor through the three pans is continuous, no stop requiring to be made for the discharge. The vapour rising from the boiling liquor in the 1st passes through a "save-all" (which catches any priming juice) into the steam-drum of the 2nd, whence it is removed as condense-water after giving up its latent heat to boil the liquor around it. Similarly, the vapour from the liquor thus set boiling in the 2nd passes through a save-all into the steam-drum of the 3rd, where in turn it condenses itself, parting with its latent heat to the liquor now in the 3rd stage of concentration. The vapour rising in the 3rd pan, being at so slight a tension as to part with its latent heat only at a temperature too low for it to be further utilized, passes through a save-all to a condenser, whence it rushes as condense-water into the pump. Thus almost all the heat supplied to boil the liquor and evaporate its water is used again to repeat the operations to a further extent in the 2nd and 3rd pans. Hence the economy of fuel, as compared with ordinary steam evaporating-pans. The temperature of the liquor in the 1st pan is below that of the same liquor boiling in the open air; it is reduced for the denser liquor in the 2nd pan, and still further for the most concentrated liquor in the 3rd pan, in consequence of the progressive completeness of the vacuum.

Rillieux's Triple Apparatus.—Norbert Rillieux's improvements in triple-action apparatus, with the object of attaining a maximum useful effect, are as follows:—The recipient for discharge-steam

1375.



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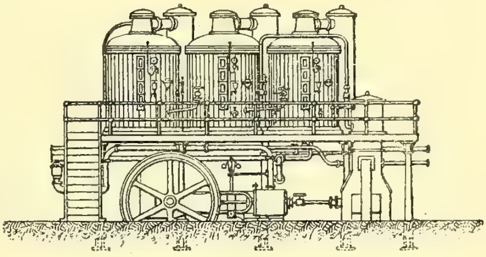
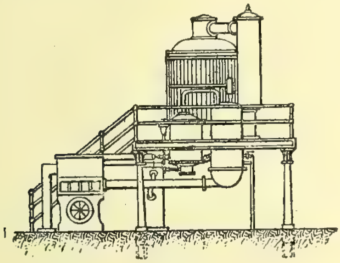
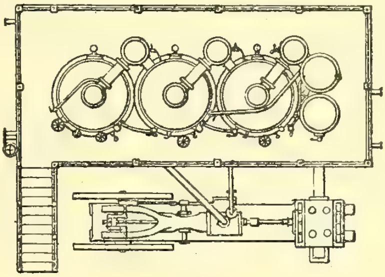




1377.



1378.

(A, Fig. 1379) is provided with an equilibrium-valve C, which regulates the maximum quantity of steam that can be used. The first recipient being the steam-generator of the entire apparatus, and heated by the discharge-steam of all the engines, is also connected with the discharge-water from the coils of the boiling-pan D through the check-valve *a* and pipes *b*. By this means, the small excess of steam that escapes with the water, assists in heating the first pan, while the combined condense-water from the coils and pan passes off through another pipe *d e* into a reservoir *g* for the feed-pump to the generators.

To effect boiling with double action, considerable pressure is required in the first pan,—$\frac{1}{2}$–$\frac{3}{4}$ atmos., and even more, according to the size of the coils. The vacuum is very small in the second pan. The pressure is regulated by introducing into the feed-vessel for the triple-action a sufficient quantity of direct steam, so that it does not interfere with the action of the apparatus. To maintain normal pressure in the first pan, special apparatus is provided. If the boiling-pan is heated by direct steam at high pressure, the discharge is conveyed to the 1st evaporating-pan; if steam from the expansion-chamber is used, or escape-steam from the engines, the discharge from the boiling-pan is conveyed to the 2nd evaporating-pan; if steam from the 1st evaporating-pan is used for boiling, the discharge passes to the 3rd evaporating-pan, and thence to the condenser. In triple-action apparatus, the 1st evaporating-pan is provided with two small auxiliary pans, one to evaporate the syrups that have been subjected to osmosis, the other for evaporating the saline liquors, both being connected to the same condensing-column. Improvements are also made in the pumps for drawing off the condense-water from the 2nd and 3rd evaporating-pans. To obtain maximum effect from the apparatus, it is necessary to maintain a considerable vacuum in the last pan. The condensation is effected by bringing the steam into contact with very extended surfaces, over which water flows in thin films, thus obtaining a very complete contact of the steam with the water. The steam from the safety-chamber is, as usual, subjected to a water-jet.

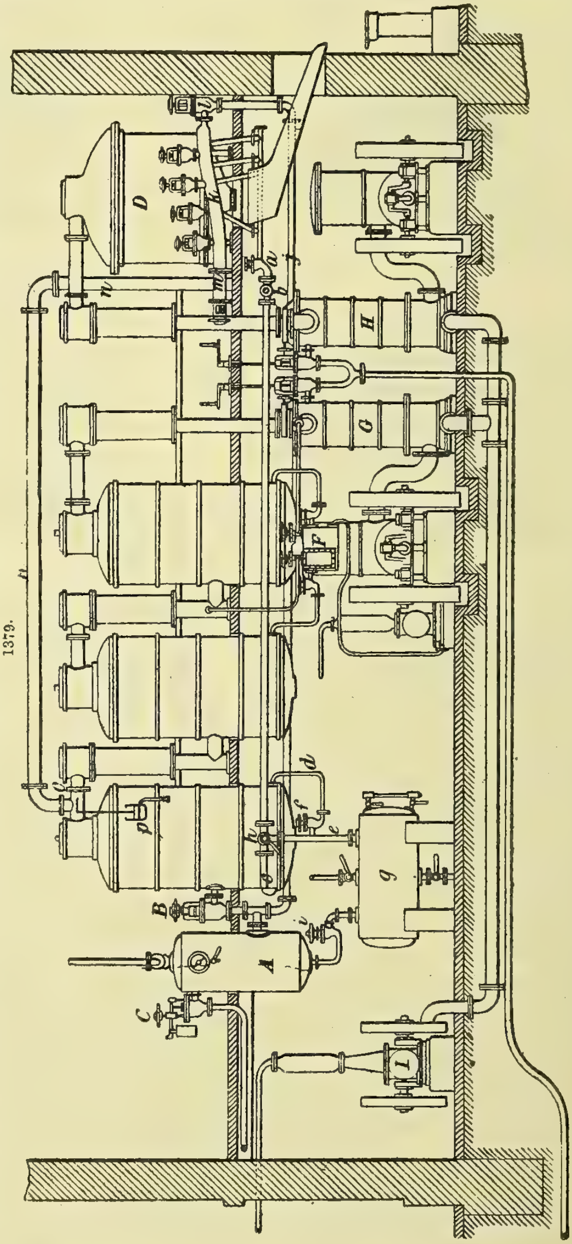
The system is receiving considerable attention from beet-sugar makers in France, though devised more especially for cane-sugar. One manufacturer, whose diffusion process gives a very low juice (sometimes only $2\frac{1}{2}$° B., and generally not more than $3\frac{1}{4}$° B.), states that with the ordinary arrangement of the triple-effect he evaporated 1800 *hectol.* (of 22 gal.) of juice at 3·2° B., with 150 *hectol.* of milk of lime, making a total of 1950 *hectol.* to 18° B. per 24 hours; with Rillieux's modification, he evaporated to 25° B., which, with the increased quantity worked off, is equal to a total evaporation of 5158 *hectol.* per 24 hours, or a gain of 3208 *hectol.* This gain is said to be effected at the cost of only a little (quantity not stated) additional steam. The Rillieux apparatus is now rarely used in Louisiana, being considered too complicated for plantation purposes; the tendency there is towards very large single vacuum-pans.

e. Bath-evaporators.—This system may be illustrated by the plan adopted by F. A. Bonnefin, of Guadeloupe, whose capillary filter has already (p. 1889) been described. The apparatus is intended for use with the filter, and is made by the same firm.

The tempered juice, prior to evaporation, passes through a "continuous preparator," a metallic vessel 32 ft. long and 18 ft. broad, divided by partitions into 4 chambers of 2 ft. in width; each chamber has a central partition not quite extending to one end, with holes for the inlet and outlet of a heating liquid, which therefore travels 36 ft. in the chamber, on leaving which it is reheated. On the partitions, is a copper pan divided so as to form a continuous zigzag channel, about 1100–1700 ft. long, the bottom being immersed in the heating liquid circulating in the chambers below. The juice is admitted at one end, and issues at the other. Along one side of the pan, are hollows to collect the heavy bodies deposited during the flow of the liquid.

The juice, introduced at 15° (59° F.), being in contact during a travel of 1100 ft. or more with a liquid at about 99° (210° F.), leaves the further end of the pan at 80°–90° (176°–194° F.), deprived of heavy organic or inorganic matters in suspension, and of light matters which become separated and rise to the surface. It successively fills capillary filters (p. 1889), and is delivered in a pure state to be concentrated.

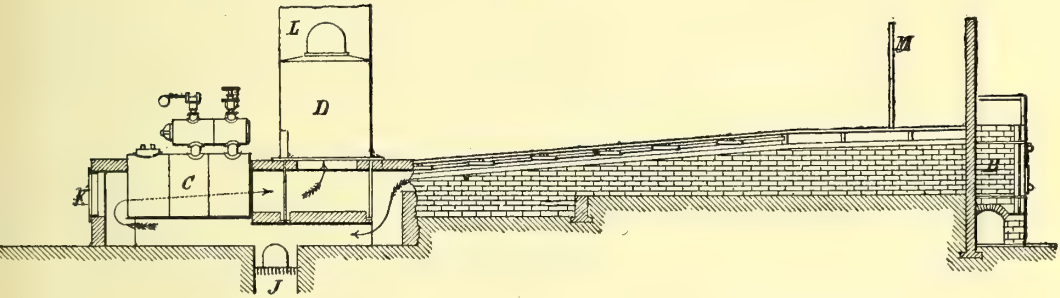
The vacuum-pan is constructed like the preceding, with modifications to maintain the heat in the coils at about 99° (210° F.), the heat being regulated in proportion to the juice being more and more concentrated, and always below 100° (212° F.) For generating heat, Bonnefin employs a small furnace for heating oil to 250°–280° (482°–536° F.). This hot oil is conveyed through a coil of pipes in a vessel containing water, and connected with the vessel which receives all the condense-water of the factory. After the oil has done duty in the evaporating apparatus, it is returned to be reheated by the furnace.

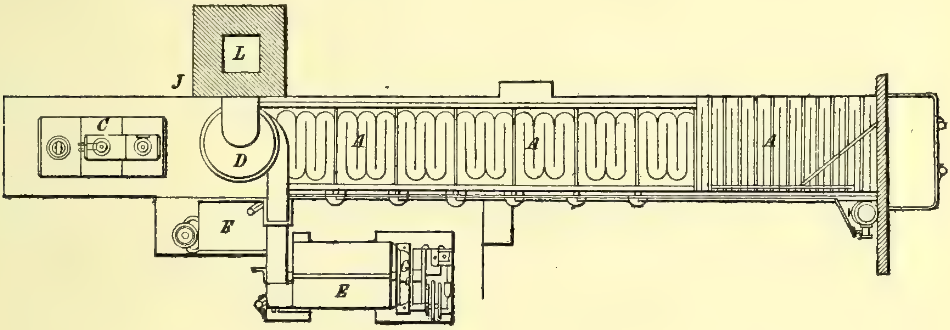


1379.

f. Fryer's Concretor.—In Fryer's concretor, no attempt is made to produce a crystalline article, but only to evaporate the liquor to such a point that when cold it will assume a solid (concrete) state. The mass is removed as fast as formed, and being plastic while warm, it can be cast into blocks of any convenient shape and size, hardening as it cools. In this state, it can be shipped in bags or matting, suffering neither deliquescence nor drainage. The cost of an apparatus capable of making 10 cwt. per hour is about 1000*l.* It is the invention of Alfred Fryer, of Manchester and Antigua, and is made by Manlove, Alliott, Fryer, & Co., Nottingham and Rouen. It is shown in side elevation and plan in Figs. 1380, 1381. It consists of a series of shallow trays A, placed end to end, and divided transversely by ribs running almost from side to side. At one end of these trays is a furnace B, the flue of which runs beneath them; and at the other end, are a boiler C and an air-heater D, which utilize the waste heat from the flue, employing it both to generate steam and to heat air for the revolving cylinder.

1380.





1381.

The whole series of trays A is placed on a slight incline, the upper end being next the furnace. The topmost 3 trays are made of wrought iron, since the intense heat here would render cast-iron liable to fracture. The clarified juice from the pipe M flows first upon the tray nearest the furnace; it runs down the incline towards the air-heater D, meandering from side to side in a shallow stream. Thus it has to traverse a channel 400 ft. long, before it can leave the trays at the end adjacent to the air-heater, although the distance between the furnace and the air-heater in a direct line is not quite 50 ft. While flowing over these trays, the juice is kept rapidly boiling by means of the heat from the furnace; and although it only takes 8–10 minutes to traverse, its density is raised from about 10° B. to about 30° B.

From the trays, the thickened syrup flows into the tank F, and thence passes out into the revolving cylinder E. The cylinder is full of scroll-shaped iron plates, over both sides of which the thickened syrup flows as the cylinder revolves, and thus exposes a very large surface to the action of hot air, which is drawn through it by means of a fan G. Motion is given to the whole apparatus by means of a small engine. In this cylinder, the syrup remains for about 20 minutes, and at the end of that time, flows from it at a temperature of about 91°–94° (195°–200° F.), and of such a consistency that it sets quite hard on cooling. By the use of dampers, the hot gases from the flue may be directed either under the boiler, returning through it to the heater, or direct to the heater. At J, is an auxiliary furnace for raising steam, when the heat from the concretor flue is insufficient or not forthcoming,—as, for instance, when beginning to crush canes, and before the juice has covered the trays. K is a smoke-door for cleaning out the boiler-tubes. L is a chimney, either of brick or iron, for the last escape of the gases.

F. J. G. Minchin, of the Aska Sugar Works, Ganjam, Madras, gives the following result of using

Fryer's concretor with diffusion-juice. It was in work 2 months, during which period there ran over it 1,030,680 gal. juice, and were delivered from it 500,225 gal., hence it evaporated 530,455 gal. This gives a daily evaporation of 9557 gal. For this, wood fuel was used at the rate of about 15 tons per diem. The juice ran on at 6°–6½° B. cold, and ran off at 11°–12° B. cold. The concretor was used as an auxiliary to double-effect.

W. F. Ashby has published some statistics of the use of the concretor by the Umhloti Sugar Co., Natal, from which it appears that with the 1876–7 crop, 610,900 gal. of juice gave 507 tons 6 cwt. 3 qrs. 7 lb. of sugar, or 1·86 lb. per gal. of juice; the 1877–8 crop gave, from 586,300 gal. of juice, 450 tons 15 cwt. 1 qr. 14 lb., or 1·72 lb. per gal. of juice.

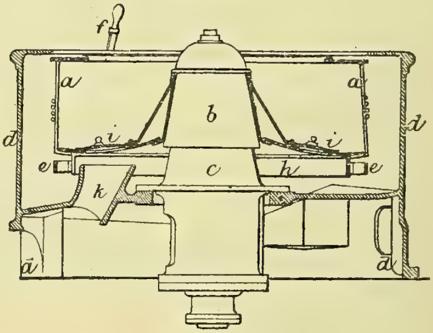
B. By Cold.—More than 30 years ago, Kneller proposed to concentrate syrups by forcing cold air through them, and his plan was much improved by Chevallier. Sugar made in Chevallier's apparatus rivalled that of the vacuum-pan in every respect. A vessel holding 200 gal. of syrup (comprised of 3 parts of sugar to 1 of water) is estimated by Wray to turn out 12 tons of sugar daily. The cost of the apparatus is small; the power required is trifling; the ordinary air of the estate could be used at once in dry weather, and would entail an insignificant expense for drying in damp weather; and the quality of the sugar is unsurpassed. In 1865, Alvaro Reynoso proposed to rapidly cool the syrup in suitable machines, and thus form a confused mass of particles of frozen water (ice) and dense syrup. The mixture is afterwards separated in centrifugals, and the syrup deprived of ice is evaporated *in vacuo* ready for crystallization. It seems most singular that, in the face of the many drawbacks and great cost incurred by concentration by heat, and in presence of the many improvements introduced of late years into refrigerating and cold-producing apparatus (see pp. 1017–20, 1134–42), so little effort is made by sugar-growers to adapt the latter system to their needs. A similar crystalline product, namely common salt (see p. 1718), is obtained by hundreds of tons from sea-water by the effect of natural cold, in favourable localities; and there would appear to be no valid reason why a modification of the plan should not succeed on an extensive scale with sugar solutions.

Curing.—"Curing" embraces the drying and whitening or bleaching of the sugar. The several plans will be discussed in succession.

Simple Drainage.—This is the oldest and crudest method. To remove a certain amount of the molasses and other impurities, the semi-liquid mass, dug out of the coolers as soon as sufficiently cold, is placed in casks with perforated bottoms; the holes in the casks are loosely filled with canes, twisted leaves, or rushes (the latter long enough to reach above the contents of the casks), in such a manner as to form a rough strainer. The casks stand meantime on rafters over an immense tank. Here the draining process slowly and imperfectly goes on, a portion of the molasses escaping into the tank below, but much still remaining in the mass of sugar, imprisoned between the minute crystals. Even after months of standing, the separation of the molasses is so incomplete that very great leakage and waste continue while the sugar is on its way to European markets. Sugar cured in this way is termed "muscovado," and is the most impure form of "raw" ("grocery," "moist," or "brown") sugar. It is nearly obsolete in the English and French colonies, and its manufacture is decreasing rapidly in Louisiana.

Claying.—The first improvement introduced is based upon the fact that the impurities of muscovado sugar are much more soluble in water than the sugar itself: thus washing with water effects considerable purification. The earliest manner of carrying this out was by placing the sugar in inverted cones with a minute aperture in the apex, stopped up during the filling and for about 12 hours afterwards; upon the mass of sugar in the cone, was placed a batter of clay and water (hence the term "claying"), the object being to ensure a very gradual percolation of the water through the mass. This water carries with it the uncrystallizable sugar and colouring matters imbedded between the crystals. The resulting sugar is much lighter-coloured than muscovado, but the grain is very soft, and the operation is most wasteful. In Bengal, a wet rag is sometimes substituted for the clay batter. The process continues but little in vogue.

1382.

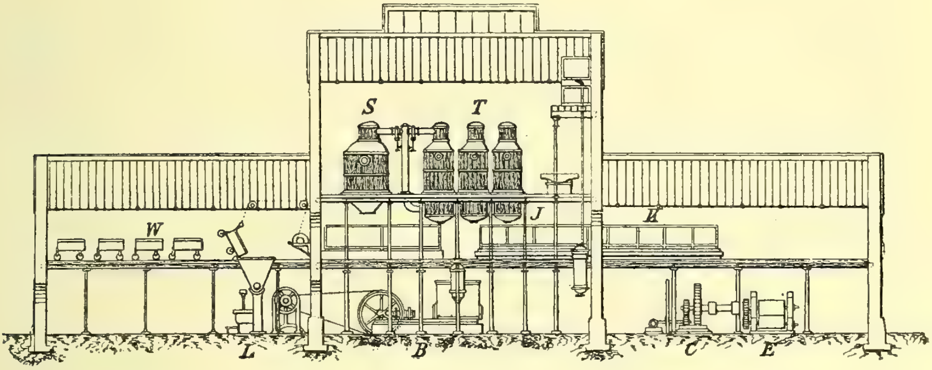


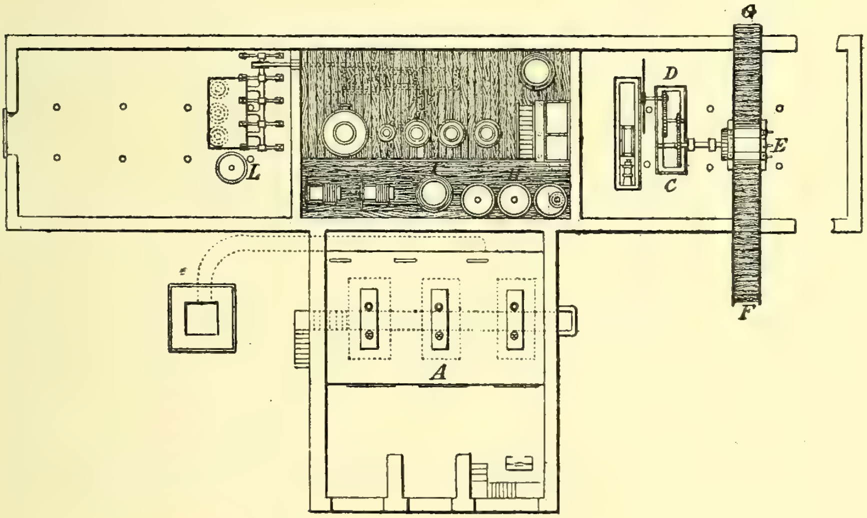
Spirit-washing.—The very slight solubility of sugar in alcohol, coupled with the ready solubility in that medium of many of its impurities, suggested the practice called "spirit-washing." This consists in substituting cold alcohol or alcohol and water for simple water. The results are not perfect, however, and the costliness of the method soon caused its abandonment in this connection.

Vacuum-chest.—The vacuum-chest consists of an iron box with a tray of wire-gauze above, and connected with air-pump suction below. The sugar is spread on the tray, and the downward suction produced by working the air-pump creates a tendency in the fluid portion of the mass to separate itself. Effectual separation, however, can only be attained when the grain or crystal of the sugar dealt with is large, hard, and well formed; with small or soft grain, the process is utterly inapplicable. This fault has restricted its use.

Centrifugals.—The preceding modes have been generally superseded by centrifugal machines or hydro-extractors. There are many varieties, but all consist essentially of a cylindrical basket revolving on a vertical shaft, its sides being of wire-gauze or perforated metal, for holding the sugar. The basket is surrounded by a casing at a distance of about 4 in., the annular space thus left being for the reception of the molasses, which is expelled by centrifugal force through the sides of the basket when the latter revolves at high speed. A spout conducts the molasses to a receiver. An example of a simple centrifugal is shown in Fig. 1382; more complicated forms are used in refineries (see Refining). The machine comprises a revolving basket *a*, carried by a cast-iron dome *b* upon a central shaft, arranged with driving-pulley, footstep, and neck-bearing, on the central bracket *c*, the whole being supported by the outer cast-iron casing *d*, which collects the liquid thrown off from the material in the basket, and conveys it away through a discharge-pipe. The brake *e*, for stopping the motion of the basket, is applied by the lever-handle *f* acting upon the angle-iron ring *h* riveted to the cylinder bottom. The sugar is discharged through two copper doors *i* covering openings in the cylinder bottom, and passes down the shoot *k* cast in the outer casing, into a receptacle below. The treatment of the molasses separated from the sugar has been already described (see p. 1895).

1383.





1384.

Complete Factory.—Figs. 1383, 1384 represent a modern sugar-house of economical and convenient design. The cane-mill and engine for driving it, with its cane-carrier and begass-carrier G F, are shown on the right. The steam-boilers are in the house A. The defecators are shown at H, and the clarifier at I. After the juice is defecated, it passes through the triple-effect T, where it becomes syrup, and is clarified in I, whence it goes as required to the vacuum-pan S, where it is concentrated and becomes *masse-cuite*, of larger or smaller grain as desired. From S, it falls into waggons W, and from these waggons it is discharged into the mixer of the centrifugals at L. These centrifugals are driven by the engine B, which works the vacuum-pump for the triple-effect and vacuum-pan. The sugar is finally packed in the area P, and delivered at the door on the extreme left of the house.

Maple-sugar.—The rock or sugar-maple (*Acer saccharinum*) is a tall ornamental tree, flourishing throughout most of the N. American continent. In sections of the United States where it has not been exterminated, the manufacture of sugar and syrup from it is a remunerative adjunct to other farming industries, occupying a period in which little other farm work can be pursued. The apparatus for collecting the sap and manufacturing the sugar, involves a very small investment; the fuel consumed usually consists of the prunings of the maple grove, which is benefited thereby; and at least 90 per cent. of the gross return is net profit.

An interesting point connected with the production of maple-sugar, is the variability of the flow of the sap, dependent on diurnal changes of weather. The rising of sweet sap commences immediately after the first break-up of the long frost, about mid-February, continuing through March and into April, but varying in different localities and at different seasons. A cold N.-W. wind, with frosty nights and sunny days in alternation, tends to incite the flow, which is more abundant in the day than at night. It is, however, most sensitive to unfavourable changes, and a run of 3 gal. a day from one tree may almost cease in a few hours, and then gradually recover itself. Hence the yield from day to day is uncertain, and reliable statistics are difficult to record. A continuous course of favourable weather tends to the largest production, a rising and falling supply reducing the total of the season. The flow commences earliest in warm and low situations. A thawing night is said to promote it; it ceases during S. winds and at the approach of a storm. On the S. and E. sides, it has been noticed to be earlier than on the N. and W. sides of the same tree. There are generally 10–15 good "sap days" in the season, which continues on and off for about 6 weeks; after this, as the foliage develops, the saccharine matter is reduced, and the sap is said to be "sour," though a restricted flow still continues. Emerson considers that the sugar-yield depends also on the character of the previous summer, and that plentiful rain and sunshine prepare for an abundant harvest in the succeeding spring. Open winters are thought to render the sap sweetest; while much freezing and thawing make it most abundant and of the best quality. The sap of isolated trees is richer in sugar than that of those which are massed together in the forest.

The produce of sugar may average 1 lb. to 4½–5 gal. of sap, but instances are given of 1 lb. of sugar from 3 gal. of sap. In a good sap season, an average tree will run as much as 3 gal. of sap in a day, occasionally more, and afford about 4 lb. of sugar in the season; Emerson records cases of 10, 20, 33, and 43 lb. of sugar from single trees, but such weights are altogether exceptional. The average quantity of sap per tree would be 12–24 gal. in a season. Trees under 25 years old are seldom tapped, scarcely paying for the trouble, apart from the debility it produces in them. Repeated tapping of mature trees causes no apparent injurious effect: in many instances, trees have been tapped for 40 consecutive years, and it is said that both the quality and quantity of sap are visibly improved after the first tapping.

The trees are usually tapped at a height of 3–4 ft. from the ground, with a ¾-in. auger to a depth of 2–6 in., into which a perforated plug is driven, to lead the sap into the collecting-vessels, or a simple notch 1½ in. deep is cut with the axe. One to three taps are inserted in each tree, and have to be removed in succeeding years to fresh places, generally alternated on opposite sides of the tree. In the United States, the large branches are punctured, as well as the trunk. The sap is evaporated either in iron caldrons, or in shallow boilers, 6 ft. long, 2½ ft. wide, and about 8 in. deep. Those of copper are preferred to iron, as they are said to yield a whiter sugar. Care is taken to keep the boilers filled up with fresh additions of sap during evaporation, and to stir it well with a wooden spade, till the syrup attains a sufficiently thick consistency (which is ascertained by its "breaking" or crystallizing when dropped into cold water), and exchanges its white colour for golden-yellow. It is strained during evaporation, a small quantity of lime or soda being added to neutralize any free acids that are present, and a little white of egg or milk to clear it. After straining and skimming, it is poured into pans or moulds to crystallize, and may be further clarified by gently boiling in tapering cans, with a tap at the bottom, towards which the molasses gravitates, and is drawn off as the crystallized sugar sets. Earthenware pots are said to improve the colour but injure the quality.

Many improvements have been made in the manufacture during the last few years. Formerly the highest attainments only resulted in a fine muscovado-like sugar; but now, specimens are exhibited vying with the best loaf-sugar. This has been effected by greater cleanliness in the preparation of the sap, and improvements in draining and refining the sugar. A few years ago, a premium was awarded by the Oswego County Agric. Soc., New York, to R. Tinkor, for the following method of preparing maple-sugar. The sap is boiled in a potash-caldron to a thick syrup, strained while warm, let stand for 24 hours to settle, then poured off, leaving back all that is impure. To clarify 50 lb., 1 qt. of milk, 1 oz. of saleratus, and the whites of two eggs are well mixed; the sugar is then boiled again, until it is hard enough to lay upon a saucer, and finally allowed to stand and cool. Very little stirring will prevent it caking in the caldron. For draining, a funnel-shaped tube, 15 in. sq. at the top, and coming to a point at the bottom, is used. The sugar is put in when cold; a tap is inserted at the bottom, and a damp flannel cloth of two or three thicknesses is kept on the top of the mass. When drained, the sugar is dissolved in pure warm water, and clarified and drained as before.

Maple-sugar is made mostly for the home use of the producers, and as an article of merchandise it seems in a fair way of extinction. Thousands of splendid trees are yearly cut down and converted into broom-handles; and at the present rate of destruction, maple-sugar will before long be unknown in the trade. The amount of maple-sugar made in the States is reported at 40 million lb. annually, but this is considered to be ⅓ below the actual quantity. According to the last census returns, Vermont reported a yield of almost 10 million lb. The production of New York is somewhat larger, but nothing compared with the difference in area; in 1860, there were in this State about 10 million acres planted with sugar-maples at the rate of 30 to the acre. The only other States which return more than 1 million lb. are:—Michigan, 4; Ohio, 3¼; Pennsylvania, nearly 3; New Hampshire, 2¼; Indiana, 1½; Massachusetts, 1. The total production of maple-molasses is 1,500,000 gal., of which, Ohio returns nearly 400,000; Indiana, nearly 300,000; Kentucky, 140,000; and Vermont only 16,000. In addition to the large production of maple-sugar in the States, the estimated quantity made by the Indians living east of the Mississippi is 10 million lb. per annum, and the quantity manufactured by those living west of the river is set down at 20 million, but is probably much greater. The maple-sugar product of Canada was stated in 1849 at 2,303,000 lb. for the Lower Province, and 4,161,000 lb. for Upper Canada. The census of 1851 gave the total at 10,000,000 lb., exclusive of what was used locally without being brought to market. The market value fluctuates between 8 and 22 cents (4-11*d.*) a lb., according to the ruling prices of cane-sugar.

In Nebraska, no maple-sugar is made, but an equally good article is manufactured to a considerable extent from the ash-leaved maple or box elder (*Negundo fraxinifolium*), growing on the banks of rivers from Pennsylvania to Carolina. Some investigations made in Illinois, with reference to its value for sugar, are reported to decide—(1) That it produces more sap than the sugar-maple of equal size, ½ gal. per day being obtained from a small tree of 3½ in. diam. and 5 years old; (2) that the sap is richer in sugar—the yield of dry sugar averaging 2·8 per cent. of the weight of the sap; (3) that the sugar produced is in general whiter than that from sugar-maple treated in the same way. These facts should recommend this tree to the attention of planters, especially in prairie regions.

Melon-sugar.—The preparation of sugar from the melon (*Cucumis Melo*) is fast assuming some importance in America. The long delta between the rivers Sacramento and San Joaquin, California, when reclaimed by embankments, is exceptionally productive. Melons constitute a crop that never fails in this climate, and a factory has been erected on Andros Island to work up the melon-juice derived from a large area at small expense for transport. Water-melons with white pulp are preferred, and it is said that seed obtained from Hungary has yielded plants whose fruits surpassed any produced from native American stock. The plants are set out at distances of 12 ft. apart one way and 6 ft. the other. Their leaves cover the ground and kill all weeds before the latter have time to develop. Besides, they form an impenetrable mulching, which keeps the soil moist.

The juice of the melon is asserted to be free from those non-saccharine bodies which make the extraction of beet- and cane-sugars such an expensive matter. On the other hand, the sugar is uncrystallizable, and does not amount to more than 7 per cent. of the weight of the fruit. Usually the juice is only evaporated to such an extent as to afford a syrup, the ordinary yield being 1 gal. of syrup from 8 gal. of juice. The flavour of melon-syrup is said to be much superior to that of common beet-sugar. The cost of production is set down at 5½ cents (2¾*d.*) a lb., as against beet-sugar at 7 cents (3½*d.*). One grower in California made 125 bar. of syrup in a single season several years since. No doubt is felt that melons would thrive luxuriantly in New Jersey, Delaware, and Maryland. The same may be said of all sub-tropical lands possessing a sufficiently damp climate. It must also be remembered that the seeds afford a valuable oil (see p. 1395), and that the pulp and seed-cake are excellent food for cattle.

Milk-Sugar, Lactine, or Lactose (Fr., *Déchet de lait*; Ger., *Schottensand, Zuckersand*).—This is obtained from milk by precipitating the casein with a few drops of dilute sulphuric acid, and filtering and evaporating the liquid. Crystals are deposited, which are purified by re-dissolving and treating with animal charcoal. In Switzerland, considerable quantities of milk-sugar are prepared by evaporating the whey which remains after the separation of the cheese. At Marbach, Canton of Lucerne, Switzerland, half-a-dozen refiners are said to make a handsome income from the manufacture of milk-sugar. The raw material used for the recrystallization comes from the neighbouring Alps, in the cantons of Lucerne, Berne, Schwyz, &c.; a considerable quantity is supplied also by Gruyères. Notwithstanding rises in the price of the raw material, consequent upon the demand, and increased cost of labour and fuel, the manufacture continually expands, and now amounts to 1800–2000 cwts. yearly, with a gross value of about 12,500*l.* The manufacture of the crude sugar is only carried on in the higher mountains, because there the whey cannot be used profitably for fattening swine, which are found chiefly in the valleys; and the wood required for the evaporating process is cheaper in the highlands.

The crude sugar is sent to the manufacturer or refiner in sacks containing 1–2 cwts. It is washed in copper vessels, and dissolved to saturation at the boiling temperature over a fire; the yellow-brown liquor, after straining, is allowed to stand in copper-lined tubs or long troughs to crystallize. The sugar-crystals form in clusters on immersed chips of wood; these are the most pure, and therefore of rather greater commercial value than the milk-sugar in "plates," which is deposited on the sides of the vessels. In 10–14 days, the crystallization is complete, and the milk-sugar has finished growing. The crystals are then washed with cold water, afterwards dried in a caldron over a fire, and packed in casks holding 4–5 cwts. As the crude sugar can only be obtained in summer, the recrystallization is not carried on in winter. The entire manipulation is carried on in a very primitive manner: with a more rational method of working, a whiter and finer quality of sugar could probably be produced. Milk-sugar finds its chief application as a basis for homœopathic medicines, and in infants' foods.

Palm-sugar.—Palm-sugar, often called date-tree sugar, is a product of the juices of many kinds of palm, the most important being the wild date-palm (*Phœnix sylvestris*), which thus gives a name to the whole class. Other species are the palmyra (*Borassus flabelliformis*), (see p. 932); the coco-nut (*Cocos nucifera*), (see pp. 939, 1353, 1383); the gomuti (*Saguerus* [*Arenga*] *saccharifera*), (see pp. 919, 1827); the nipa (*Nipa fruticans*), (see p. 985); and the kittool (*Caryota urens*), (see p. 938). All these are essentially natives of the E. Indies, including India, Ceylon, Siam, the Malay Peninsula, and the E. Archipelago.

The portion of British India particularly occupied by this cultivation extends nearly due E. and W. from Kissengunge, in Kishnagur, to a little beyond Nollchit in the Backergunge district; and N. and S., from the vicinity of Comercolly in the Pubna district, to the borders of the Sunderbunds, thus occupying on the map a surface of about 130 miles long by 80 broad. Its principal districts are Jessore, Furreedpore, and Backergunge, with portions of Nuddeah, Baraset and Pubna; beyond this tract, little or no date-tree sugar is manufactured, although the tree is often cultivated in other districts, and may be occasionally met with in most parts of India.

Here one species only, *Phœnix sylvestris*, is availed of, though many others might be profitably utilized. From *Cocos nucifera*, good *goor* is commonly made in Province Wellesley; and from *Borassus flabelliformis*, throughout Bengal, a saccharine juice is obtained, used for intoxicating purposes (see Beverages—Toddy, pp. 425–6), frequently as a substitute for yeast in making bread, and is said by the natives to yield a sugar of good grain and greyish complexion.

The sugar obtained by the natives of Bengal and Siam from the various species of palm is, on account of the crude way in which it is manufactured, of very inferior quality, and is mainly consumed in the countries where it is grown. The juice of the nipa palm (*Nipa fruticans*) is almost equal in saccharine richness to that extracted from the sugar-cane, with the advantage that it is much cleaner, and contains no colouring matter nor chlorophyll; the vegetable matter being easily precipitated, it gives a liquor as clear as spring-water. This species, flourishing near the sea, or on the edges of brackish pools, takes up a large quantity of salt, which makes its appearance in the juice, in quantity sufficient, in some cases, to give the liquor a decidedly saline taste. Were it not for this drawback, a large quantity of excellent sugar would be obtained from this source.

The date-palm (*Phœnix sylvestris*) requires a humid soil and climate, and flourishes best in the vicinity of water, though it must be above the reach of annual inundations from the rivers. The trees are planted by the natives mostly in the hedges surrounding the fields appropriated to rice and other grain. Where regular plantations have been attempted, the trees are placed 10–15 ft. apart, so that sufficient space is left for cultivating an oil-seed or other dry crop between them, without its being injured by the shade of their leaves; indigo is said to be the only crop which suffers through not obtaining the full benefit of the sun's rays.

As the modes of planting the tree, extracting the juice, and boiling down into *goor* differ but in trifling details throughout the date-tree tract, a description of the routine practised in the principal district, Jessore, will serve for the whole.

Planting.—The trees are always raised from seed. The fruit ripening in June–July, the seeds are collected and sown shortly afterwards a few inches apart, in a moist spot near the cultivator's house. They are weeded and watered occasionally during the following dry season, and are ready for planting out in the succeeding April–May, after the first showers of the season. The ground is well ploughed, and without any manure, the plants are placed each in a hole made with the hoe or *kodaul.* By the time the rainy season closes, about the following October, they are strong young trees, the leaves 3–4 ft. high; vacancies are then filled up. The roots are occasionally cleared of weeds; and should the ground not be in yearly crop, a ploughing is sometimes given, as this loosens the earth around them and allows more scope for the roots. No other expense or trouble is incurred in their cultivation. The trees arrive at full growth at about their 7th year, but the native cultivator seldom allows them to reach beyond 5 years, before commencing to extract the juice; should the young trees be forward, he even commences at 2 or 3 years old, though this early exhaustion injures the after-productiveness of the plant, and probably shortens its life. Frequently the trees are tapped when the stem is less than 1 ft. high from the ground, a hole being dug in which to lodge the earthen pot that collects the juice. When not weakened by too early tapping, the average age the trees arrive at is about 30 years, being 25 years for sugar production after allowing the first 5 for their undisturbed development. On the borders of the Sunderbunds, however, where the trees grow in strong marshy soils impregnated with salt, it is said that their excessive vegetation causes them to exhaust their strength sooner, and that their age in such places does not exceed 17–18 years.

The quantity of juice obtained before the trees have reached their 5th year is small and uncertain; if allowed their full 5 years for growth, and first cut in their 6th year, the juice for that year is found to be yielded in the proportion of about one-half the yield of a tree of full maturity; in the 7th year, three-fourths of the full quantity; and it is not until the 8th year that the tree is found to give its full average yield of juice.

The natives reckon a *beegah* to contain 160 trees, or two *puns* of 80 each, planted about 10 ft. apart; then the cost may be estimated thus:—

				R.	A.	P.	
160 plant-trees, sowing, watering, &c.				1	0	0	
Planting, and filling up vacancies				1	0	0	
Half-yearly* rent of 1 *beegah* of ground at 2 Rs.	1	0	0				
Ploughing twice per annum, at 2 annas	0	4	0				
Weeding ditto ditto, at 4 annas	0	8	0				
Yearly expense	1	12	0				
Which, for 5 years, is				8	12	0	
				10	12	0	(21*s.* 6*d.*)
Add compound interest on the yearly account, at 25 per cent. per annum				10	7	2	
Nett cost of 1 *beegah* of trees ready for producing R.				21	3	2	(42*s.* 4¾*d.*)

* The other half being chargeable on the other crop grown between the trees.

Cutting the Trees and Collecting the Juice.—The trees are first cut about the 20th October. This is done by stripping off the lower leaves of the branching head of the tree on one side, so as to leave a denuded space 1 ft. long; from this, a piece of the bark is removed in the shape of a triangle, each side of which is about 8 in. long, and having one angle pointed downwards. For the next 8–10 days, the cut part is left to harden, and what little sap exudes from it is allowed to run to waste, as not being sufficient for use. Collecting the juice, therefore, does not commence before about the 1st November, a few days earlier or later, according to the season, the first cold nights causing the sap to run freely. As soon as this is observed by the *gauchea* or date-tree labourer, he ascends the tree in the evening, and slices away a further portion, cutting deeper this time, so as to divide the sap-vessels, and from the centre of the triangle towards its sides, in such a way that along the latter a sort of channel is formed, which conducts the juice to the lower point of the triangle; here in a notch is inserted one end of a piece of reed or grooved stick, about 6 in. long, its other end hanging over the earthen pot which is suspended by a string close under it, and into which the juice trickles as it flows from the tree. The instrument used for cutting the trees is a *daw* or billhook, of peculiar shape.

A man having less than 80 trees lets them out, at a yearly rent for their use, to a neighbour who has more, as they would not yield sufficient juice to compensate for the expense of the necessary arrangements. The number worked by any one ryot or family varies from 80 to 300–400; but for facility of calculating the expense, a farm of 160 may be assumed, all full-grown, and capable of yielding the average quantity of juice. Whatever the number of trees, they are lotted off into 7 equal divisions. The trees of one division are cut every evening in succession, so that the whole are cut regularly once in 7 days. The first division may be taken as containing 23 trees, on which the work proceeds as follows. The *gauchea* having cut this number, and suspended the pots on the previous evening, obtains in the morning, as their 1st day's produce, an average of 10 *seers* (of 2 lb. 1 oz.) of juice from each tree; on the 2nd morning, 4 *seers*; and on the 3rd, 2 *seers*; after this, the reed and pot are removed, and for the 4th, 5th, 6th and 7th days, the trees are left to recover themselves, the little juice that still exudes being allowed to run to waste, as not worth the labour of collecting. On the evening of the 7th day, these 23 trees are again cut; this is done by peeling off a further portion from the already open cutting, which again divides the sap-vessels, and the juice recommences flowing; and the same process is repeated throughout the season. Thus the ryot by newly cutting a $\frac{1}{7}$ division of his trees every evening, will have every morning to gather the juice from 3 divisions, yielding respectively 10, 4, and 2 *seers* of juice from each tree; by this system, a uniform quantity of juice is daily procured, and the labour is equally distributed over the time given for it. The ryot having 160 trees would collect daily the juice of 68 or 69, yielding juice as follows:—

	M.	S.
23 trees first day's runnings, at 10 seers each	5	30
23 ,, second ,, ,, 4 ,, ...	2	12
23 ,, third ,, ,, 2 ,, ...	1	6
Total juice per diem from 69 trees	9	8 (758 lb.)

This refers only to the juice exuding during the night, and collected early in the morning, from which alone sugar is made. It is sometimes customary, with trees which bear well, to collect what may run from them during the day; but as rapid fermentation takes place soon after sunrise, the day-juice is unfitted for crystallization into *goor*, and is boiled up only for sale as molasses. This practice, however, is far from general, and, at the ordinary market rate for molasses, barely repays the labour required. The *gauchea* commences collecting the juice a little before daybreak; as soon as a sufficient number of pots are collected to commence a boiling, they are carried to the boiling-hut. The emptied pots from the trees are ranged on the ground in rows of about 20 each, with their mouths downwards over a layer of straw or dry leaves; the latter is then set fire to, and gives the pots a thorough smoking, covering their inner surface with an even black coat. The object of this is to prevent acidity, which would set up fermentation in the fresh juice, were any of that from the previous night allowed to taint the vessel, but which is neutralized by the alkaline salts contained in the smoke. As an additional slice is pared from the face of the incisions in the trees once every 7th day, this forms towards the end of the season a very deep notch, reaching sometimes nearly half through the trunk. Each succeeding year the trees are cut on opposite sides, so that they have, when a few years old, a deformed zigzag appearance.

Boiling the Juice.—This is conducted in 4 shallow earthen pans, about 2 ft. diam. and 1 ft. deep, set in a square furnace, formed by digging a hole in the ground, and raising a mud structure over it, about 6 ft. sq., in the dome of which are cut the 4 holes in which the pans are set. A hole on one side for feeding the fire, and on the other for the escape of the smoke, completes the arrangement of the furnace; over this, a light roof is usually thrown, supported by bamboos, and thatched with the dried leaves of the date-tree, as a partial shelter from the sun and rain, though the latter is unusual during the season when the work is in progress. The fuel used is the *soondry* wood, with which the date districts are all more or less easily supplied from the neighbouring Sunderbunds, assisted by the dried leaves of the date-tree itself.

The 4 pans are kept about half-full of date-juice, and as the contents diminish by evaporation, fresh juice is supplied, until each is sufficiently filled to complete the boiling into *goor* without further addition. Up to this point, skimming goes on, and the small end of a date-tree leaf is kept floating in each pan, as it is believed to assist the clarification, though probably a mere fancy. No lime nor other alkali is used: the juice is simply boiled until it arrives at its proper granulating consistency, which is known to the natives by long practice, from the appearance of its tenacity when allowed to drop from the end of a stick, and from its colour and appearance while boiling. The juice, as brought from the trees, is clean, white, and transparent, resembling that of the coconut, both in appearance and taste, though much sweeter. These qualities give it a decided advantage over the juice of the sugar-cane, it being quite uncontaminated with feculencies, the separation of which from cane-juice causes so much trouble. The skimmings from the boiling of date-*goor* are consequently trifling, and probably consist principally of vegetable albumen. They are turned to no useful purpose.

The boiling occupies 5–6 hours with each pan, and as soon as it is complete, the *goor* is ladled into a vessel near. If it is intended for immediate sale to the *moyrah* (sugar-maker), this vessel is a long jar-shaped earthen pot, holding 2 *seers* to $\frac{1}{2}$ *maund*,—the size and form varying much. If the pots are large, they are not filled at once, but the boilings of several days are poured in successively, so that 3, 4, or more pots are filled simultaneously, and contain layers slightly varying in quality, though the average in all is the same. A great deal of *goor* is, however, converted by the ryots themselves into a description of sugar called *naund-dulloah*, in which case the boiling is not carried to so high a point; and this allows it to form a larger crystal, and to part with its molasses more freely. In such case, it is ladled at once from the boiling-pans into a large *naund* (conical-shaped vessel) holding 2–3 *maunds*, and in this it is cured and drained in the simplest possible manner.

Returns.—Dry cold weather is most favourable for the date-juice, both as to its quality and yield; the *goor*-manufacturing season in Bengal extends on the average over 3½ months, from 1st November to 15th February. Little is made earlier than the former date, and such is generally of small grain, and inferior; any made later than mid-February is of soft grain, and contains an undue proportion of molasses. Occasionally the warm weather sets in earlier, and cuts short further *goor*-making, though if there be a good fall of rain, this is followed by a temporary return of cold nights: the *goor* season may then be said to commence anew, and very fair produce is obtained even in the first days of March. The finest yield is in December–January, during the coldest part of the season; and on the whole, the estimate of 3½ months (107 days) is the time occupied by an average season. In estimating the yield of good *goor* for a season, ⅕ of the total should be deducted for the diminution caused by unpropitious weather. Thus, 160 trees yielding 9 *maunds* 8 *seers* of juice per diem throughout the season, multiplied by 107 days, and allowing ⅕ deduction for loss by variations of the weather, leaves bazar *mds.* 787–20–13 (56,964 lb.) as the nett produce in juice for the season, and this, divided over 160 trees, gives *mds.* 4–36–4 (356 lb.) as the average total produce of juice from each tree. The proportion of *goor* obtained from date-juice averages $\frac{1}{10}$ by weight, and the density of the latter does not appear to vary nearly so much as that of cane-juice. At this average, the yield by the above calculation from 160 trees would be bazar *mds.* 78–30 (5702 lb.) of *goor*, or nearly 19¾ *seers* from each tree, or 49 *maunds* 8¾ *seers* (3554 lb.) per 100 trees per annum.

The expense of extracting and collecting the juice, and converting it into *goor*, is calculated as follows:—

	R.	A.	P.	
Cultivating 160 trees on 1 *beegah* of ground, as before calculated, = R. 21–3–2; assuming these trees to be in full bearing for the average 20 years, the expense per annum is	1	0	11	
Half the annual rent, at R. 2 per *beegah*	1	0	0	
Labour of collecting and boiling the juice; 2 *gaucheas* at R. 3 per month each, and one headman at R. 4 to boil the *goor*, can fully manage 200 trees, on which their wages for 3½ months will amount to R. 35; for 160 trees	28	0	0	
Earthen pots for holding *goor*, say 296, of 10 *seers* each, and costing 12 *annas* per 100	2	3	6	
Earthen pans for boiling, extra jars, &c.	6	0	0	
Soondry wood fuel (in addition to dried date-tree leaves) for boiling *goor*, 400 *mds.* at R. 5 per 100 *mds.*	20	0	0	
Knives, ropes, and boiling utensils	1	0	0	
Setting up furnace and *chopper* roof	1	0	0	
	60	4	5	
Deduct value of *soondry* wood charcoal from the furnace	1	0	0	
Nett cost of 78¾ bazar *mds.* (5645 lb.) of *goor* at the average rate of 12 *annas* (1*s.* 6*d.*) per *maund*	59	4	5	(5*l.* 18*s.* 6½*d.*)

From an estimate of the quantities of palm-sugar purchased for European refineries, added to the native refined sorts sold for export in the Calcutta market, under the names of *gurpatta* and *dobarrah*, Robinson concluded that 9500–10,000 tons, or at least ⅕ of the whole annual quantity of sugar exported to England from India was in 1850 composed of palm-sugars. The attention bestowed by Europeans on the production of these sugars for the Calcutta or home markets, has been confined to the remanufacture or refining of the native raw material (*khaur*, *dulloah*, &c.); for this purpose, it is held in great esteem, producing a good-coloured and well-crystallized sugar, and yielding a greater percentage in weight of refined goods than can be obtained of equal quality from the same weight and class of cane-sugars. On the other hand, raw palm-sugars are more liable to deteriorate by being kept in store, losing both colour and strength rapidly; this applies, however, to the raw products only, the refined or reboiled sugars bearing transport and storage as well as those from cane.

The cause of these peculiarities appears to lie in the larger proportion of gluten present in palm-sugars; they are no less remarkable in the molasses than in the sugar itself, that from palm-sugar possessing far less saccharine matter, and being of much darker colour than that from cane, which is probably caused by the gluten being partly decomposed by the lime and heat of the boiling process. Another distinguishing feature is the absence from palm-sugar of the empyreumatic oil observable in the cane product, and which gives to rum its well-known flavour.

Considering the low cost of palm-sugars, and the little trouble and risk incurred in rearing the trees, it seems at first glance remarkable that European planters have not entered upon this cultivation for producing sugar on a large scale. But discouragements no doubt exist in the nature of land-tenure in Bengal, the length of time the trees occupy in coming to full bearing, and the difficulty of collecting the juice for boiling into sugar by the European method after they have been reared. It has been shown that the annual produce of a full-grown plantation is equal to 78¾ *maunds* of *goor* per Bengal *beegah*, which, converted into *khaur*, may be taken as equivalent to about 5½ tons of muscovado sugar per acre.

Sorghum- and Maize-sugar.—The saccharine value of the graminaceous plants known as N. China cane, Guinea corn, millet, durra, imphee, sorgo, &c. (chiefly *Sorghum saccharatum*, *S. vulgare*, and *S. caffrorum*), has for ages been recognized in Africa and China; and it would seem that sugar was extracted from maize (*Zea Mays*) by the ancient Mexicans. Of late years, new attention has been attracted to these plants as sugar-producers, principally in the United States, but also in Canada, Australasia, India, England, and France.

Qualities.—The cultivation of sorghum, maize, and pearl-millet, and the manufacture of sugar from their stalks, were made the subject of extensive experiments by the U. S. Department of Agriculture, during 1879, and again since. The investigations demonstrate little difference between the various kinds of sorghum as sugar-producers; and seem to prove that each of them is, at a certain period, nearly as rich in sugar as the best sugar-cane. This maximum content of sugar is maintained too for a long period, and affords time to work up a large crop.

The varieties grown and investigated were Early Amber, White Liberian, Chinese, and Honduras sorghums, and pearl-millet. The analyses of each of the plants in successive stages showed that the uncrystallizable sugar diminishes as the true sugar increases. They differ widely in the date when the crystallizable sugar is at its maximum, but are alike in that it is attained at about the same degree of development, viz. at full maturity, as indicated by the hard dry seed, and the appearance of offshoots from the upper joints of the stalk. Analyses of several sorghums after they had been subjected to a very hard frost, sufficient to form ice ½ in. thick, and continued for 4 days, exhibited no diminution of crystallizable sugar, and no increase of uncrystallizable; but the influence of the subsequent thaw was noticeable in the diminution of crystallizable and increase of uncrystallizable sugar. Thus it would appear that protracted cold is not injurious to the quality of the canes, but that they should be worked up before they have thawed.

The Early Amber, Chinese, Liberian, and Honduras sorghums, and the pearl-millet, were planted on the same day, May 15, 1879. The relative weights of the different kinds of stalk are:—Early Amber, average of 40, 1·73 lb.; White Liberian, average of 38, 1·80; Chinese, average of 23, 2·00; Honduras, average of 16, 3·64.

These were grown side by side on land of equal fertility, and afford data for calculating the average yield of each per acre. Early Amber and Liberian closely correspond in their development. While these two attain a sugar-yield equal to average sugar-cane by mid-August, the Chinese does not reach this condition until late September, and the Honduras not until mid-October. An average of all the examinations of the four sorghums during the periods when they were suitable for cutting gives the following results:—Early Amber, Aug. 13–Oct. 29 inclusive, 14·6 per cent. crystallizable sugar; Liberian, Aug. 13–Oct. 29, 13·8 per cent.; Chinese, Sept. 13–Oct. 29, 13·8 per cent.; Honduras, Oct. 14–29, 14·6 per cent.

Varieties.—The Department now has 30–40 varieties of sugar-producing sorghums, all valuable to a greater or less degree, according to the soil, climate, cultivation, seasons, and process of manufacture. Other useful varieties are doubtless to be obtained. The so-called "Honduras" sorghum is only one of the kinds indigenous to Honduras; and there are probably several varieties growing in Central America, and even as far south as the Rio de la Plata in S. America. Early Amber is the favourite variety with planters in Minnesota and the N.-W. Minnesota Early Amber is claimed as an improvement upon the Early Amber, obtained from selected seed sent to a more southern latitude to be grown and then returned to Minnesota.

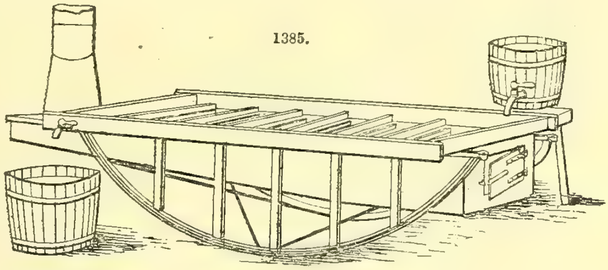
Early Amber receives its name from its early ripening, and from the bright amber colour which characterizes its syrup when properly made. It is very rich in saccharine matter, and when properly treated, its products are devoid of the peculiar "sorghum" taste formerly complained of, the flavour being similar to that of pure honey. The Chinese sorgo is about the same height as the Early Amber. Its seed-heads are fuller and more compact, somewhat resembling a head of sumach, whence the synonym "sumach-cane." White Liberian is rather taller than Early Amber. The stalk curves at the top, leaving the head pendent; hence the synonym "Gooseneck." It is also styled a variety of the White Imphee. The Honduras cane grows about one-half taller than either of the other varieties. Its seed-top is reddish-brown and spreading; hence its name "sprangle-top." It is also called "mastodon" and "honey-cane."

Cultivation.—Soil.—Some cultivators fear that new land imparts a strong flavour to the syrup. Others say that old land produces a syrup of brighter colour, but not of better flavour. An advantage of new timber land is the small amount of cultivation required. Costly culture on old land will not pay in opposition to cheap culture on new land. New land is comparatively free from foul seed, and consequently less liable to weeds. If it is necessary to clear old land of weeds, or to fertilize it with farmyard manure, a crop of corn should first be grown on it. General opinion is in favour of a sandy, upland soil, well drained, but not freshly manured. Manuring spoils the flavour of the syrup. The majority of cultivators are in favour of indefinite repetition of the crop on the same soil. Some have cultivated the same ground for 7 years without deterioration, the product ranging from 250 to 300 gal. of syrup per acre. The soil is not required to be very rich. Land too poor for wheat has given 200 gal. per acre of excellent syrup.

Preparation of the Ground.—Fall (autumn) ploughing, putting the plough to the beam, causes all foul seed, and especially pigeon-grass, to germinate in the fall, and be killed in winter. Another advantage is that the crop is less liable to injury from droughts in the early season. A large crop can be raised the first year on open prairie and at the first breakage, especially if the La Dow harrow be used. When the ground becomes sufficiently warm in the spring, some go over it with a Beaver Dam seeder, and then with a drag and roller. This treatment effectually disposes of the grass, generally considered of first importance.

Time of Planting.—The cane should be planted as early as it is possible to work the ground properly, avoiding late frosts. The ground should be well warm before the seed is put in. In Minnesota, the average seeding-time is early May; it should not be quite so early on ground impregnated with grass-seed. If postponed till the season is warm enough to germinate the seed quickly, better results may be got, as a late spring frost may cut down early plants, and, before they grow again, pigeon-grass is apt to start up profusely.

Seed.—By steeping the seed in warm water for 24–48 hours, it becomes sprouted, and grows more rapidly; but a dry season will kill the sprouted seed, and the crop will be a failure. Seed brought from the latitude of St. Louis is in great favour. Some Minnesota growers send their seed to Missouri and Kansas to have a crop grown and its seed returned. Seed imported from S. Indiana produced, on its first sowing, stalks 12–15 ft. high; but by planting the seeds of each crop, its successor showed a declining height, until it was but 7–8 ft. The sugar-yield also diminishes. The deterioration of the seed is generally not very marked till the third year. Southern seed excels less in an earlier ripening of the crop, than in increased product, in some cases amounting to one-third. The seed has a value of its own for feeding hogs, sheep, and poultry.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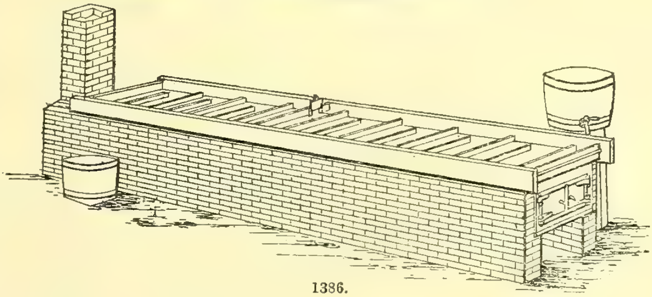

1386.

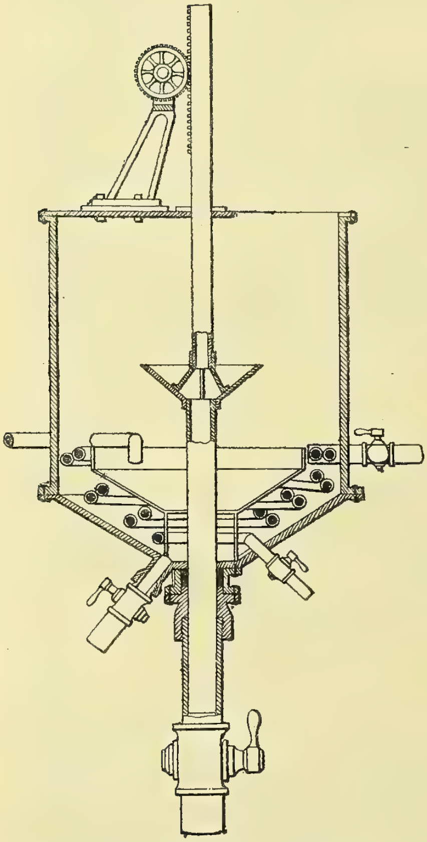
Planting. — Planting must be deep enough to secure moisture, hence, early plantings should be shallower than late ones. Some growers plant in rows 3–3½ ft. each way, and use 2 lb. of seed per acre, or 6–7 seeds to the hill, thinning out at the second hoeing. Seed should not be planted in the trough of the marking furrow, where heavy rain is apt to wash it away, but on the edge. Others plant at 15–18 in. one way and 3 ft. the other, the rows running north and south. A tract of 4 acres sown broadcast produced at the rate of 450 gal. per acre. Many planters practise stepping upon the seed as placed in the ground, urging that the close pressure of the soil around the seed enables it to germinate more rapidly. Stepping the seed causes the ground to bake, if it is wet clay.

Culture.—The leading point presented in the culture is keeping clear of weeds. This requires prompt action with the hoe, drag, and cultivator. The plants are too tender for Thomas's harrow. The crop should be thoroughly hoed, until large enough to cultivate with the plough or cultivator.

Time to Cut the Cane.—The best results may be got from early cuttings, if there is a risk that extremely hot weather will invert the crystallizable sugar. The proper time is when the seed is in the "stiff dough," or from Aug. 28 to Sept. 1. The juice seems to improve for a few days, but afterwards it begins to decline in saccharine matter. The earlier the cutting after the seed has reached the dough stage, the larger the product, and the brighter and cleaner the syrup.

Harvesting.—With regard to stripping off the leaves, it is urged that if the leaves are put through the mill with the stalk, they absorb a large portion of the juice, but this should not be the case with mills of sufficient power. The cost of stripping the leaves before cutting is estimated at $15 (3*l.*) per acre, and it would not pay unless labour were plentiful and cheap. The Agriculture Department experiments show little or no difference between stripped and unstripped cane, although the mill used was an indifferent one. The cane should be cut, some say, at 6–8 in. from the ground, and others, at the first joint. The top should also be cut off at 18 in.–2 ft. Some planters lay the cane in windrows, and others oppose the practice, as exposing the leaves, if not the stalks, to mildew. Some insist that cut cane should be immediately placed under cover, to avoid evaporation by the sun; others pile in ridges 4 ft. high, and cover the mass with marsh hay, laying poles along the piles every 2 ft., in order to admit fresh air; others again pile it as sugar-cane is sometimes piled in the field, crossing the hills in such a way as to secure ventilation, and shed the rain. Crops kept in these different ways for several weeks are reported to have produced large and fine syrup returns.

1387.



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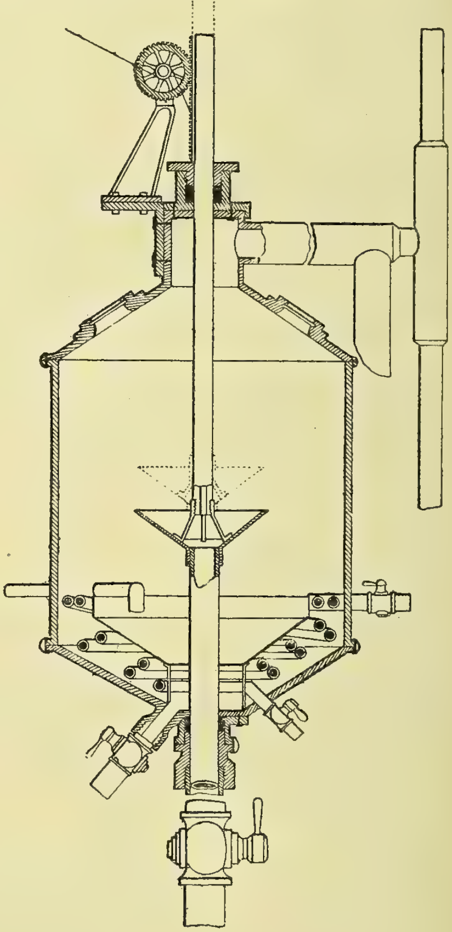
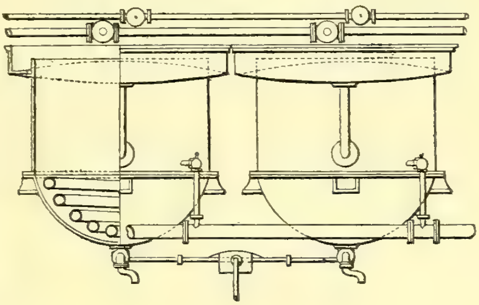


Transport to the Mill.—It is best for the farmer to manufacture the cane as well as raise it. In moving the cane from the field, there is much to be said in favour of bundling it. Some decapitate it with a broad axe, after binding. The points to be kept in view, both in the transportation and in the storing of the cane, are protection from the weather, and such ventilation through the mass as will prevent mildew.

Manufacture.—The extraction of the juice from sorghum-stalks, and its conversion into sugar, is almost an exact repetition of the operations connected with the manufacture of cane-sugar (see pp. 1860–1902). The machinery and apparatus are identical in principle and purpose, but are usually constructed on a much smaller scale, as well as being often of a portable nature.

Crushing-mills.—The Victor mill, made by the Blymyer Company, Cincinnati, is in very common use in the United States. It is arranged either vertically or horizontally, and is adapted to all kinds of motor. There are 7 sizes. The smallest requires 1 H.P., gives 40 gal. of juice per hour, weighs 395 lb., and costs about 10*l.*; the largest takes 4 H.P., runs 170 gal. per hour, weighs 1900 lb., and costs about 46*l.*

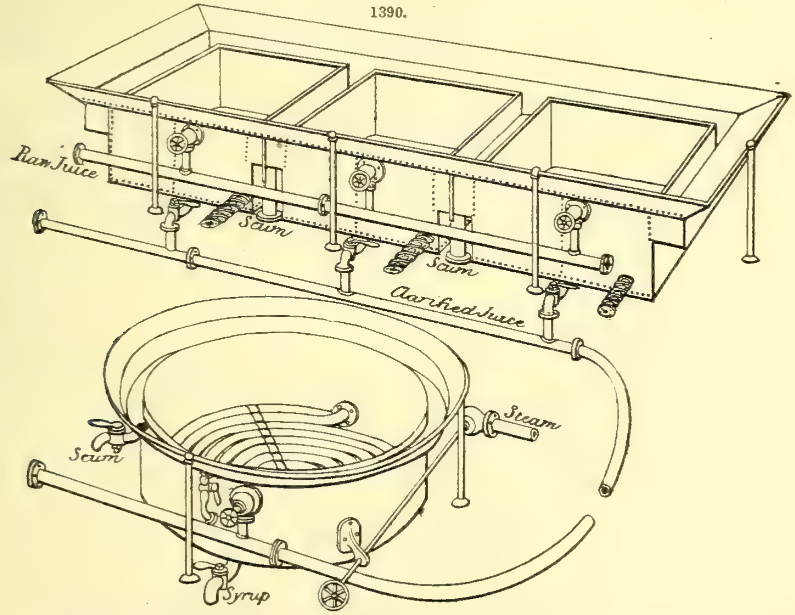
1389.



Evaporators.—Figs. 1385, 1386, show respectively a portable and stationary Cook evaporator made by the same firm. The former consists of pans 44 in. wide, and 6–9 ft. long, ranging in capacity from 40 to 90 gal. a day. When the pans are of galvanized iron, they cost 13–17*l.*; when of copper, 11–14*l.* more. Each contains a portable furnace. The whole can be lifted into a wagon by two men, and conveyed thus from field to field. The stationary evaporators are made in 7 sizes, 44 in. wide, and 6–15 ft. long. With a capacity of 40–180 gal. a day, the prices are 6–18*l.* for galvanized iron, and 16–42*l.* for copper.

Fig. 1387 shows McDowell's evaporator, 6 ft. diam. and 2 ft. deep. It is furnished with steam-coils 125 ft. long, and a diaphragm directing the currents of evolution over the steam-coils, up the outside, and down the middle axis. In the centre, is an adjustable funnel-shaped skimmer, which can be raised or lowered to the level of the boiling juice. It catches the scum, and delivers it by a pipe through the bottom of the evaporator. Two evaporators will reduce 600 gal. of defecated juice by one-half in 1½ hours.

1390.



McDowell's concentrator, Fig. 1388, differs in having a closed top and a water-jet condenser, producing a vacuum. In this, 600 gal. of evaporator-juice are reduced to 200. The product is then "semi-syrup," and can be stored, or shipped to a refinery, or further reduced in a vacuum-pan.

Fig. 1389 is a direct steam evaporator, which boils clarified juice by means of a steam-coil, the scum passing over into the trough around the upper edge.

Fig. 1390 is a steam-train, made at the Colwell Iron Works, New York. It consists of 3 clarifiers, and an evaporator, requires little labour, dispenses with pumps and ladles, and finishes the syrup up to the vacuum-pan.

1391.

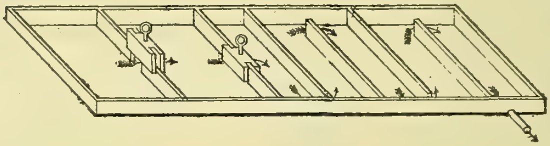
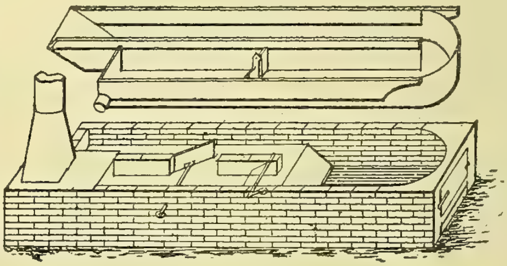


Fig. 1391 is a cheap home-made evaporator, which can be put together by an ordinary mechanic. It is constructed by putting wooden sides and ends upon a galvanized iron or copper tray.

Fig. 1392 shows Stubb's evaporator. The first compartment occupies $\frac{3}{4}$ of the whole pan, leaving $\frac{1}{4}$ for the second. The juice enters the first compartment near the smoke-stack in a regular stream, passing around the semi-circle over the fire-box to cross-partitions, where it thickens to a semi-syrup. Being over the hottest part of the furnace, it rises to a light foam, which breaks to the lowest point where the cool juice enters, not only keeping back the green scum, but carrying all the scum off 30 ft. of surface, where it is scraped off without loss of sugar. The semi-syrup is turned into the second compartment at intervals, to be finished under full control of heat governed by dampers.

1392.



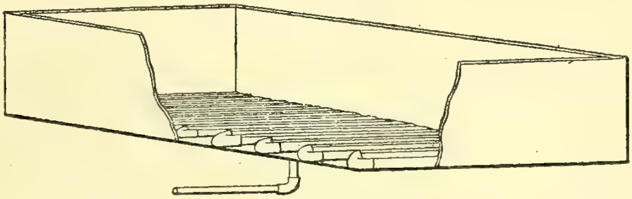
Defecators.—Fig. 1393 is McDowell's defecating-tank, 8 ft. long, 5 ft. wide, and 2 ft. deep. The bottom is covered with a steam-coil, and contains a strainer, through which the clear juice can be drawn. Each tankful can be treated in 30 minutes. Two of these tanks suffice to defecate 600 gal. per hour.

Fig. 1394 represents the apparatus required in F. L. Stewart's process: a defecating-tank D, a short 10-gal. cask C, a lacquered funnel F with indiarubber ring around the neck, a plug *r* for thrusting into the throat of P, and a piece of indiarubber piping R. Directions for its use are as follows:—Place the cask on a bench nearly level with D. Pour 1 gal. of water into the cask, then pour $\frac{1}{2}$ gal. sulphuric acid into a wooden bucket, allow it to flow thence into the cask, and well mix it. Next insert the rubber-covered neck of the funnel tightly into the larger hole in the head of the cask. Compress one end of the long tube slightly, and insert it in the smaller hole. Insert the plug with the rubber ring around it in the throat of the funnel closely, and it will be air-tight. This is then ready to work, as indicated in section 6.

Some of Stewart's patent powder is dropped quickly, 1 lb. at a time, through the funnel into the cask containing the diluted acid, the plug is quickly inserted, and immediately sulphurous oxide escapes through the tube into the clear juice in the tank D; 1 lb. of powder is usually sufficient for 150 gal. of juice when its gas is all discharged. The juice must absorb the gas until it becomes acid. Never allow the cask to get more than half-full of the mixture, or the sulphuric acid may foam over into the juice and decompose some of the sugar. Lift the end of the rubber tube out of the tank when the gas ceases to flow, or the juice may be forced back into the cask. In factories where 1000 gal. of juice are run into the defecating-tank at once, a 40- or 50-gal. cask should be used. The sulphuric acid is neutralized when about an equal weight of the powder has been dropped in; therefore 1 gal. of acid poured into 2 gal. of water will eliminate the gas from about $14\frac{1}{2}$ lb. of the powder. When this proportion has been reached, or when the gas ceases to flow upon the addition of more powder, empty the contents of the cask, preserving the fine sediment for use as a fertilizer: it is principally sulphate of lime. Rinse out the cask, and go on as before.

The complete operations are:—(1) Heat the freshly-expressed juice in a copper or tinned-iron vessel to 82° (180° F.); (2) stir in gradually milk of lime until the red test-paper turns blue: about 3 pints to 100 gal. of juice is generally needed; (3) heat rapidly to the boiling-point, and then shut off the heat, or remove the vessel from the fire; (4) as soon as the sediment begins to settle, siphon off the clear liquid from near the top into cooling- or defecating-tank, until at least $\frac{9}{10}$ of the juice has been removed, leaving a thick muddy sediment at the bottom; (5) sweep out this muddy sediment with a broom through a large opening at the bottom of the heater, into a smaller vessel below, and rack off any clear juice that afterwards separates from it, and add to the contents of the defecating-tank; (6) into each 150 gal. of this clear and partly cooled juice in the defecating-tank D, introduce as much gas as is produced by operating with 1 lb. of the powder, or until blue litmus-paper is reddened; (7) the juice is run into the evaporator, and boiled rapidly in as shallow a bed as possible, removing any scum that forms: it should continue acid until the close of the boiling; (8) before the syrup has become very dense, it is passed from the evaporator into the finishing-pan. Evaporate here rapidly to a dense syrup, stirring constantly at the last, when a white cloud begins to be seen in it at about 113° (235° F.); turn out into the cooler, and remove to a warm place to crystallize; when cooled to about 38° (100° F.), stir a few grains of sugar in to hasten it.

1393.



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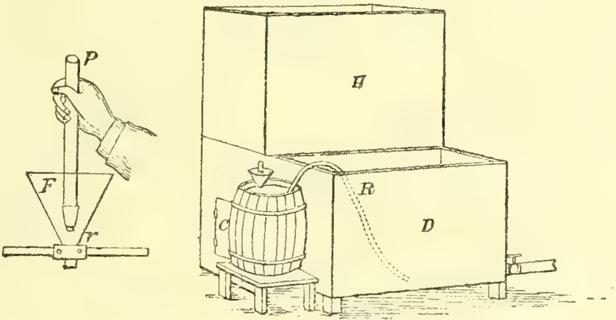
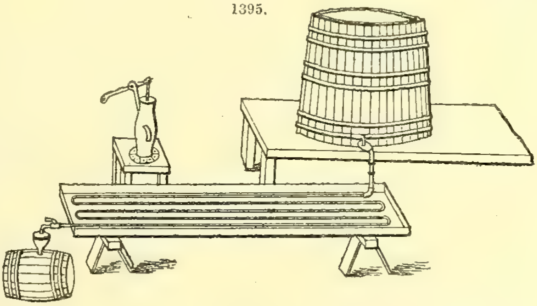


Coolers.—Fig. 1395 shows a very convenient arrangement for cooling syrup.

Complete Factory.—Fig. 1396 illustrates the arrangement of a complete sorghum-sugar factory. The juice, after running from the crushing-mill into a tank on a lower level, is pumped into the juice-tank *a*. *b* is the defecator; *c*, settling-tanks; *d*, supply-tank for evaporator *e*; *f*, supply-tank for strike-pan *g*; *h*, receptacles for scum; *i*, trucks for conveying the syrup to the sugar-room. The cost of such a factory is about 2000*l*. for a small size.

Local Details.—In New South Wales, sorghum has been found to stand frost better than the sugar-cane proper, and is little affected by floods. It comes to maturity in 5 months, and therefore may be employed as an interval crop, alternating with sugar-cane, and keeping the sugar-mills going. In 1868, there were 296 acres planted with sorghum in various districts; but in 1872, this was reduced to 32 acres. Growers expect $1\frac{3}{4}$–2 tons of sugar to the acre. When not grown for sugar, the plant yields abundance of valuable food for cattle, at the rate of 30–40 tons of cane per acre.

1395.



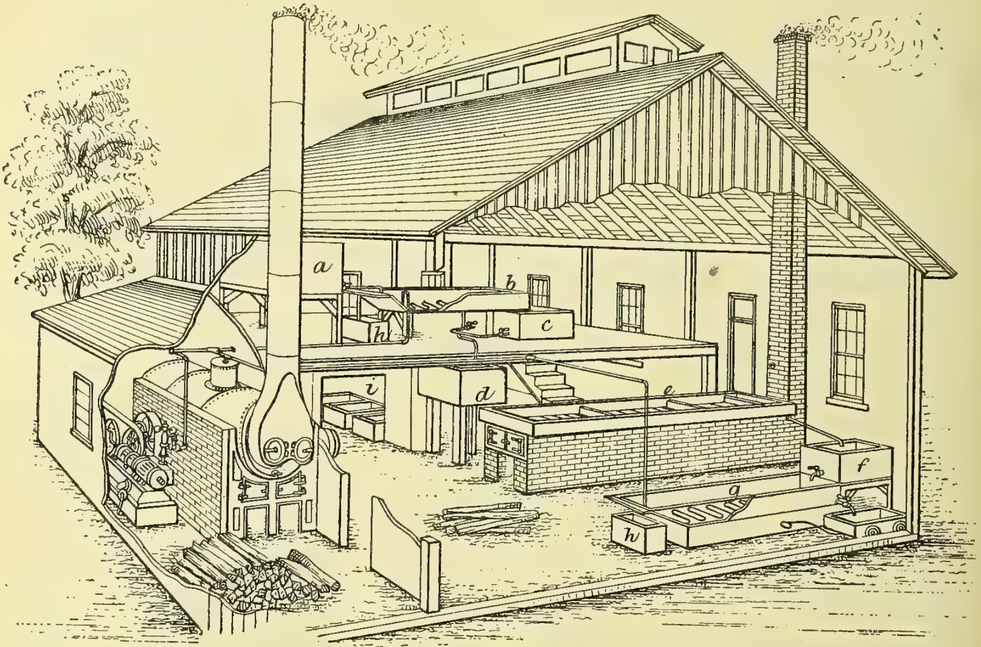
In France, Vilmorin states that it is capable of yielding on an average, from an acre of land, 26,000 lb. of juice, containing 10–13 per cent. of sugar; and that is more than the average yield of the sugar-beet. It is alleged, however, that the plant is adapted to only a few parts of S. France.

Wray asserts that some of the varieties which he introduced from Natal gave 30 cwt. of sugar per acre, and that it has yielded from a poor hand-mill 68 per cent. of juice, containing 15 per cent. of sugar. Where the sugar-cane has yielded 30 cwt., sorghum has given 25, but then there is often a second and a third crop to be obtained within the year. Sorghum can in many localities be advantageously utilized for preparing syrup. For this purpose, the juice is expressed at the time of flowering, and simply evaporated; the yield is about 100 gal. per acre.

Since 1855, its cultivation has steadily increased in many countries. It is grown in France and Algeria, for alcohol chiefly; in Italy for its syrup in wine-making.

In the N.W. States of America, where it flourishes, there were in 1864, 366,670 acres under sorghum, and sorghum-sugar was selling in Chicago at 4½*d.* a lb. In 1860, nearly 7 million gal. of sorghum-syrup were produced in the United States. This had increased in 1870 to 16,050,089 gal., and 24 hhds. of sorghum-sugar were made. In Kansas, there were 23,026 acres under sorghum in 1875. The produce was 2,542,512 gal. of syrup. Sorghum is cultivated to a considerable extent in the Ohio belt of counties, W. Virginia. It is used entirely for the manufacture of syrup for home consumption, where the locality has been more or less denuded of its maple-trees. Most persons prefer the syrup prepared from the maple (see pp. 1902–3) to that from sorghum, as the latter has too commonly an acid taste. The total production for W. Virginia was given in 1876 at 780,829 gal.

1396.



W. Ingram has reported on experimental cultivation of Minnesota Early Amber sorghum, on the Duke of Rutland's estate at Belvoir, in the season 1880. Two sowings were made in April: one within the shelter of a frame, and one in the open ground. In the latter instance, the seed failed to germinate in April, and only a few grains vegetated in May. This was much owing to the ungenial weather. The portion sown in a frame appeared in April, and made rapid and healthy growth. But owing to the subsequent very unfavourable weather, the crop failed to reach the point of maturity indicated by production of seed, and did not attain sufficient ripeness to elaborate the juice in sufficient quantity for experimental manufacture of sugar. It seemed, however, to promise a valuable nutritious food for pigs. The occurrence of severe frost in October completely destroyed the crop, showing that it must be harvested before the end of September, or early enough to secure it from frost. The seed cannot with safety be sown so early as April, and probably the 2nd or 3rd week in May would be early enough; the rows need not be more than 2 ft. apart. The inherent vitality of the plant is encouraging. After being checked and injured by 3 months of cold, wet weather, with the arrival of a little warmth, it speedily regained health, and made active and vigorous growth. In America, the best results have been obtained on light loamy soils, resting on porous subsoil. The plant will bear removal from its seed-bed remarkably well.

Starch-sugar, and other Glucoses.—Under this head, are included the various factitious sugars, syrups, and brewing compounds, obtained by the artificial conversion of starch (see pp. 1821–9) into sugar, and from the refining of cane-sugar.

Formation.—From the theories of different chemists concerning the formation of dextrine (see pp. 1645–7), and the transformation of starch into dextrine and starch-sugar, the following conclusions may be deduced:—(1) Starch torrefied at a temperature not exceeding 180°–200° (356°–392° F.)

is largely transformed into dextrine. (2) Starch heated with diluted acids changes in the first place into soluble starch, and then into dextrine and starch-sugar. The quantity of the sugar formed depends on the concentration of the acids, and increases considerably during the period of its action, while the amount of the dextrine at the same time decreases. (3) Starch heated with a solution of diastase (malt-extract) will likewise at first change into soluble starch, of which the larger part is first turned into dextrine and the lesser into sugar. The quantity of starch-sugar will depend mainly on the temperature under which the diastase operates. A large quantity of sugar is formed at 60°–65° (140°–149° F.); but at increased temperatures, say 65°–75° (149°–167° F.), larger quantities of dextrine are formed, until finally, by continued increase of temperature, the diastase itself is destroyed. (4) Sugar formation increases during the action, by the diminution of the dextrine, especially when the sugar formed is caused to ferment by yeast, and is thereby removed. The quantity of sugar formed but little exceeds that of the dextrine, even in the most favourable cases.

Principles of Manufacture.—Starch-sugar finds no application which mixtures of crystallizable and uncrystallizable sugars cannot fulfil, and is merely a substitute. Hence its manufacture is only advantageous when it can be produced more cheaply than cane- or beet-sugar. The article appearing in commerce is very often far from being pure grape-sugar, and contains upwards of 50 per cent. of water and unfermentable substances. The relative quantity of sulphuric acid used in the transformation is of importance, as the time needed for conversion is dependent upon it. The transformation occurs much more rapidly when 2 than when 1 per cent. of sulphuric acid is added. Boiling under increased pressure also reduces the time of the operation. The sulphuric acid remains unchanged by the process; but a full explanation of its action has not been given. It can be removed from the liquid by carbonate of lime.

According to calculation, every 220 lb. of dry starch should furnish 238 lb. of dry sugar, corresponding to 264 lb. of crystalline starch-sugar, if the transformation were perfect. But complete transformation does not occur until after the lapse of 36 hours, or even longer, when, by the simultaneous action of the sulphuric acid upon the sugar that had been formed many hours previously, large quantities of other products accumulate in the solution. The products of decomposition thus formed constitute a greater evil than the small quantities of dextrine otherwise retained in the finished sugar. Too long boiling of the starch with sulphuric acid produces an entirely useless article. The transformation of starch into dextrine and starch-sugar by diastase (malt) occurs most rapidly and completely at the "mash" temperature of 60°–65° (140°–149° F.). The formation of soluble starch in this case takes place in a very short period. Starch-gum and -sugar are produced simultaneously, and the starch-gum (dextrine) itself cannot be completely transformed into sugar, even by continued action of the diastase; if, to the solution thus obtained, about 1 per cent. of sulphuric acid is added, and then boiled, an approximately complete transformation takes place, especially if the boiling is done under pressure.

These general remarks suggest the following rules for practice:—Pure crystalline starch-sugar can only be produced by means of sulphuric acid and long-continued boiling. A short boiling in sulphuric-acid water produces a glucose containing considerable quantities of an intermediate product between gum and sugar. The sugar thus obtained is not hard and crystalline, but soft and tough, and becomes moist in the air. From a syrup thus produced, no solid sugar separates, because the starch-gum prevents the separation. With a syrup obtained by too long boiling, there ensues a separation of starch-sugar in a grainy condition. This is considered as spoiled glucose. [The term "glucose" in America is reserved for starch-syrup which will not become solid.] Syrup prepared by means of malt alone contains a considerable amount of dextrine. By the application of sulphuric acid, after the use of malt, the dextrine can be transformed in a great measure into sugar. Starch-sugar can be made directly from potatoes, grain, moss, wood, fruits, honey, &c. In the manufacturing industries, it is mainly made from starch; but the manufacture from wood is now being carried on in one factory. In the United States, corn-starch is with but few exceptions employed; in Europe, potato-starch. Quite recently cassava-roots (see Starch—Tapioca, p. 1828) have been used; the yield from an acre of this crop is said to be 20 times as great as that from an equal area of corn.

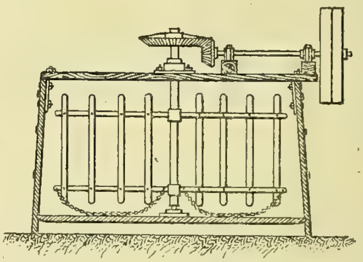
Starch-sugar appears in commerce in 5 different forms, (1) starch-syrup; (2) a sticky mass, termed "imponderable syrup" or "glucose"; (3) granulated sugar; (4) common solid sugar; (5) refined solid starch-sugar, distinguished by its whiteness and sweet flavour, which are secured by refining.

Manufacture.—The manufacture of starch-syrup and starch-sugar by means of sulphuric acid is divided into the following operations:—(1) Boiling the starch in sulphuric-acid water; (2) removal of the sulphuric acid (in the state of sulphate of lime) from the solution; (3) evaporating and refining the sugar solution. These are performed in various ways.

Boiling.—The boiling of the starch in water containing sulphuric acid is best performed in a wooden vessel by direct admission of steam, with, however, the disadvantage of introducing much water. Lining the vessel with lead is not necessary, but increases its durability. Formerly the boiling-vats were constructed in such a manner that they could be heated under pressure; but the starch becomes somewhat thin and liquid, because the steam condenses.

The modern stirring-tub (Fig. 1397) has a spiral copper worm, through which steam circulates. By this means, the mass is brought to a boil without being diluted, so as to show 19°–20° B. when cooked. There is thus a great saving of fuel. The staves for the vat are of good pine, 2½ in. thick. A vat to boil twice a day 3300 lb. of green starch, should be 8¼ ft. high. Its diameter below is 5¾ ft., and above 5½ ft.; it is open above, with a cover to be laid on, and a chimney. The chimney is square, and made of ¾-in. pine boards, 10½ in. wide in the clear, and of a height to project above the roof, to carry off the odours. The vat is placed upon a strong framework, so that the boiled starch can run into the neutralizing-coops by means of spigots above the bottom. The copper worm has a diameter of ½ in., so that it may be inserted in the vat without trouble. The rings are fastened with brass clamps. Nothing is made of iron; all screws and nuts are of copper. The condensed steam escapes at the side through a pipe connected with the copper worm and is carried to the condensed-water tank.

1397.



The requisite quantity of water is placed in the vat, and heated to boiling, after the previously diluted sulphuric acid has been added. The starch, mixed with lukewarm water to a milky consistency, is gradually run into the vat from the stirring-tub, while the liquid in the boiling-tub is kept at a constant boil. As the starch deposits quickly from the starch-milk, the solution must be constantly stirred. The larger the quantity of the boiling liquid, the less tendency there will be towards the formation of a paste. If no stirring-vat for the starch-milk is placed over the boiling apparatus, the starch-milk must be poured into the boiling sour water in portions. For each 220 lb. of air-dry starch (holding 10 per cent. of moisture) about 40–55 gal. of water, and generally 4½ lb. of sulphuric acid are used, when syrup is to be produced; for the manufacture of solid sugar, the acid may be increased to 8¾ lb. The water stated includes that used for stirring the starch. The quantity must at any rate be such that the worm in the converter is covered. As the starch used in glucose-factories is generally prepared there, and as the green starch can be well preserved in vats and barrels, it is generally applied in a moist condition; hence, instead of using 440 lb. of dry starch, a larger quantity of green starch is taken, and the water contained in the green starch is allowed for.

When the entire quantity of starch-milk is in, the boiling is continued until the transformation is accomplished. If syrup is to be produced, the boiling is of shorter duration than for solid sugar. During the boiling of potato-starch, a very disagreeable, penetrating odour is developed. At short intervals, the liquid is tested, first with a solution of iodine, and afterwards with alcohol. For the iodine test, a few drops of the sugar liquid are placed in a test-tube, diluted with cold water, and treated with a few drops of solution of iodine; when the liquid is no longer coloured violet or reddish, the transformation into dextrine and starch-sugar is finished. For the alcohol test: a little of the liquid in a test-tube is added to an equal or double volume of strong alcohol; the stronger the white separation caused thereby, the larger is the quantity of dextrine still present. Even when the precipitation ceases, some dextrine is still unchanged; a ready means for determining its complete transformation into sugar is not yet known.

Neutralization and Filtration.—When the transformation is sufficiently complete, the sulphuric acid is neutralized by the application of carbonate of lime. The acid decomposes the lime, carbonic acid gas escapes, and insoluble sulphate of lime is produced; the liquid loses its acid reaction, and becomes neutral. This operation can be conducted in the boiling apparatus, but, in most cases, is performed in neutralizing-vats. These are flat vessels, whose height stands to their width in the proportion of 1 to 3. The most suitable form of carbonate of lime is chalk, but limestone free from clay can be applied. It is indispensable that it should be in fine powder. A handful of this powder is thrown at a time into the hot, acid liquid, constantly stirred and mixed till no further ebullition ensues. Some manufacturers apply the chalk in bags, whereby the settling and refining are simplified. Each 1 lb. of sulphuric acid contained in the liquid requires 1 lb. of pure carbonate of lime; of chalk or limestone, more must be taken, as they are not pure carbonate of lime. Excess should be avoided, so as not to unnecessarily increase the sediment. As soon as titrations show a perceptible approach to neutrality, the liquid is boiled for a short period before more carbonate is added. The cessation of effervescence is a partial index of neutralization. The final additions should be of chalk-milk,—powdered chalk stirred in water to a milk, and used after the coarser parts have settled. Slaked lime is inadmissible, because it destroys the starch-sugar.

Neutralization being complete, the muddy contents of the boiling-tub are run into a wooden depositing-tank, of greater height than width, supplied with spigots for drawing off the liquid. In large establishments, a reservoir is placed in the ground adjacent to the boiling apparatus, and lined with brickwork. Into this, the contents of the boiling apparatus are drawn, and afterwards pumped into the depositing-vat. After the lapse of 12–24 hours, the sulphate of lime is deposited, so that the saccharine liquid may be drawn off. The sediment still contains a considerable amount of saccharine liquor. For the recovery of this residue, various methods have been applied, such as the following.

Filtering-barrels consist of vertically placed barrels with sieve-bottoms. Above the sieve-bottom, a piece of coarse cloth is spread, covered with cut straw or coarse river-sand, for the reception of the residue. The liquid runs out by the stopcock in the lower bottom, pure and clear. The first portion is returned to the filter. Upon the residue, gypsum-water is carefully poured, after the upper layer has been made even, and is somewhat loosened; the absorbed sugar-liquor is thereby dislodged. Or the residue is strained through bags or cloths, the press-cakes being again saturated with water, and the pressing repeated. The most general practice is to use bag-filters (described on p. 1889), or filter-presses (described on pp. 1838–9, 1848–9).

Evaporation and Refining.—The evaporation of the clear sugar-liquor is accomplished either over a direct fire or by steam. In the first case, flat pans are used, whose bottoms are only touched by the fire; in the other case, vacuum-pans. The evaporating cannot, however, be conducted uninterruptedly, since the solution yet contains dissolved gypsum, which begins to separate during the evaporation, by letting the liquid stand. The evaporating, therefore, is divided into two periods: (1) to a thin syrupy consistency, and (2) to a dense syrup after the removal of the gypsum. It does no harm to add sugar-liquor to the pan in the same ratio as the contents diminish by evaporation. The scum produced during the process is taken off with a skimmer.

As soon as the separation of gypsum makes it necessary, or when the liquor has reached a concentration of 20°–30° B., it is transferred into upright barrels, provided with spigots, for depositing and separating the gypsum. When finer cloths are put into a filter-press, the latter may also be used with advantage for separating the gypsum. When this is accomplished, after the lapse of several days, or at once if filter-presses have been used, the clear liquor is drawn off and evaporated in the same pans, or in extra pans, to a dense syrupy consistency (40°–45° B.). In large factories, vacuum-pans are used for this purpose. The deposits of gypsum from the barrels are placed in bag-filters, and then pressed.

Evaporation in open pans does not allow of economy of the steam or fuel; besides this, the liquor, when exposed to too high a temperature, acquires a dark colour, and, at the finish of the boiling, a strong formation of scum will ensue. Hence closed evaporating apparatus has for some time been used. Steam- and vacuum-pans have been already described (see pp. 1891–8).

As a brown colour is desired for glucose-syrup, if it is intended to be substituted for or mixed with cane-sugar syrups for making stout or porter, decolorization by means of bone-black (animal charcoal) is not always demanded. If the syrup is not to be decolorized, it is boiled down in the vacuum-pan to 40°–42° B. at 60°–65° (140°–149° F.), and again forced through the filter-press. The syrup, while passing through the filter-press, must be kept at a temperature of 75° (167° F.). The saccharine liquor is passed through filters of coarsely powdered animal charcoal (as is done in beet- and cane-sugar manufactories), or refined with fine charcoal, to produce an absolutely decolorized syrup, and to improve its flavour. The filtering through bone-black is best accomplished at 32° B. at 60°–65° (140°–149° F.). This is done after the gypsum has deposited itself by prolonged rest, the liquor being previously re-heated. If starch-syrup is long kept at a temperature near its boiling-point, it assumes a darker colour and becomes sweeter.

On the manufacture of solid starch-sugar, little needs to be added to the preceding remarks. Whether the syrup remains liquid, or in time congeals into solid, grainy sugar, depends less on its concentration than on its quality. If a quantity of dextrine is still present, the syrup will remain liquid even at 45° B. If the starch has been very completely transformed into sugar, the resulting syrup will, by good concentration, gradually congeal entirely to a grainy sugar. Such syrup is permitted to stand in moderately warm rooms, in wooden or earthen vessels, until it congeals. For producing a solid white sugar, the treatment with bone-black for the purpose of decolorizing is indispensable.

Liquid syrup is generally packed in strong casks or tuns of soft wood, and is liable to excessive shrinkage. During hot weather, its transportation is difficult, since the syrup often absorbs the water contained in the wood, the casks become dry, and the syrup leaks out. In case the boiling process has not been properly attended to, the product will easily ferment and spoil. Hence the article appears in commerce principally in a solid form. If the concentrated syrup, after cooling off, is stirred or beaten, it will coagulate in 8–10 hours so perfectly as to assume a soap-like consistency, without altering its quality. In this condition, it can be far better preserved and more easily transported. But liquid glucose which coagulates very quickly is not adapted to form an article of the syrup trade.

When the product is to be disposed of as solid sugar, and not as syrup, the liquor is evaporated in flat vessels to 40°–42° B., and then placed in crystallizing-pans. After the crystallization has commenced, the sticky liquid is filled into small barrels, where the mass in a short time entirely coagulates, and can be shipped. It may also be allowed to become solid in the pans, and then be ground and packed. Some manufacturers produce a dry and grainy sugar; it is then of importance that the transformation of the starch into sugar is as complete as possible, since the presence of great quantities of remaining dextrine will hinder granulation.

Common starch-sugar is identical with liquid starch-syrup, except in the proportions of water present; but in general, the composition is so varied that scarcely two samples are exactly alike, as may be seen from the subjoined analyses:—

	Starch-syrup.		Common Starch-sugar.		
	I.	II.	III.	IV.	V.
Water	21·8	20·8	27·8	27·4	26·0
Sugar	42·2	56·0	56·2	58·8	61·5
Dextrine and intermediate products	35·4	22·6	15·6	13·3	12·0
Mineral ingredients	0·6	0·6	0·4	0·5	0·5
	100·0	100·0	100·0	100·0	100·0

Other Methods.—There are a few other processes which have received application on an industrial scale. They are briefly as follows:—

Manbré's Method.—The conversion of starch into sugar proceeds much faster when the boiling takes place under pressure: upon this fact rests Manbré's method. The mixture of starch with diluted sulphuric acid is boiled at a high pressure, and at a temperature of 160° (320° F.). By this treatment, the action of the acid is increased, the transformation is more perfect, and the volatile oils which impart a disagreeable flavour are distilled off and destroyed. Use is made of a steam-boiler, constructed to withstand a pressure of 99 lb. a sq. in. (6 atmos.); it is lined inside with lead, and covered outside with a double casing. The intermediate space between the boiler and the casing is about 4 in. wide, and filled with non-conducting material. In the boiler *a* (Fig. 1398), is placed a perforated leaden steam-pipe *b*. The starch-milk is admitted by the pipe *c*, furnished with a stopcock; the boiler is supplied with safety-valves *d*, test-cock *e*, thermometer *f*, manholes *g*, receiving-pipe *h* for the products of distillation (volatile empyreumatic oils), steam-pipe *i*, liquor-gauge *k*, steam-pipe *l*, outlet-cock *m*, and water-pipe *n*.

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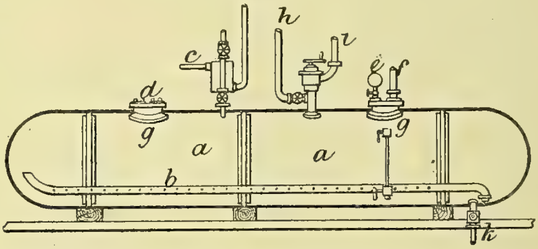

The substances are prepared for the boiler as follows:—61½ lb. of sulphuric acid at 60° B. are diluted in 6150 lb. of water. While this mixture is heated in the boiler to 100° (212° F.), a further 61½ lb. of sulphuric acid is diluted in 6150 lb. of water in an open wooden tank, supplied with a stirring apparatus. This mixture is heated by steam to 30° (86° F.). Into this latter liquid, 2464 lb. of starch are well stirred, and heated to 38° (100·4° F.). The starch-milk thus obtained is gradually poured into the boiling diluted sulphuric acid of the boiler by the pipe *c*, and the mixture is kept at a boil. As soon as all the starch is in the boiler, the cock of the conduit-pipe is closed, and steam is admitted until a temperature of 160° (320° F.) and a pressure of 6 atmos. are attained. The cocks *h i* are then opened for the outlet of steam and the products of distillation, while the temperature of the liquid is maintained by steam in the pipe *b* at 160° (320° F.), until samples taken out by the cock *k* indicate complete transformation. This is attained, according to the purity of the starch, in 2–4 hours. After ceasing to form sugar, the sweet liquor is to be drawn off, for the neutralization of the sulphuric acid, into an open wooden vessel, supplied with a stirring apparatus and waste-cock, and 185 lb. of purified carbonate of lime are stirred into 550 lb. of water, and gradually added to the liquor. The sulphate of lime thus formed is allowed to deposit, which occupies 2 4 hours. The neutral saccharine solution is filtered, evaporated, cleared, and crystallized as usual. The product is entirely pure, and free from any bitter or empyreumatic flavour.

Rössling and Reichardt's Process.—Rössling and Reichardt's apparatus for the manufacture of starch-sugar on a small scale is shown in Fig. 1399. *a* is the furnace-opening; *b*, the fireplace; *c d*, the mechanism for supporting the barrel, consisting of a ring-plate and pipe; *e*, the ashpit; *f*, apertures with pipes and cocks; *g*, the neck of the boiler; *h*, the barrel of white pine, with a bottom at least 1 in. thick; *i*, a tube made of linden or maple, 2 in. thick and $\frac{3}{4}$ in. wide; *k*, a pipe with four steam-outlets below, two of which are visible at *l m*.

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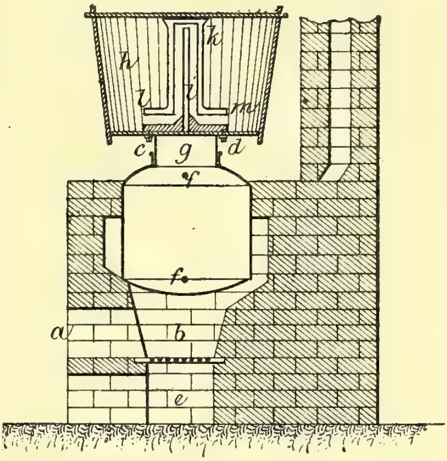


Anthon's Method.—Excellent sugar is furnished by the method invented by E. F. Anthon, and patented in many countries. The manipulation is as follows:—2640 lb. of dry starch are stirred up in 373 gal. of water to a homogeneous milk, and run uniformly into the converter, previously charged with 53 gal. of water and 48 lb. of oil of vitriol, and brought to the boiling-point, so that the mass boils uninterruptedly. During winter, the starch may be stirred with tepid water, but not so warm that it becomes pasty. When the mixture has been kept at a boil for about 1 hour after the entire mass has been emptied in, the boiling is continued for 4–5 hours longer for making hard crystallized sugar, but when syrup is intended, 3 hours' boiling suffices.

For the neutralization, 66 lb. of good bone-black and 55–66 lb. of purified chalk are used. The chalk must previously be mixed in water and strained through a fine sieve. At first, 22 lb. of bone-black are gradually thrown in, and then the chalk-milk is poured in through a leaden pipe reaching down to the lower half of the boiling-vat. But great care must be taken that the seething liquid does not flow over. When the mixture reacts but moderately acid, the adding of chalk is interrupted, and the balance of 44 lb. of bone-black is added. It is a rule that $\frac{1}{3}$ of the bone-black should be added before the chalk, and $\frac{2}{3}$ afterwards. The finished mixture is boiled gently for about 10 minutes, and passed through a Taylor-filter.

For common coagulated sugar, the syrup is condensed to 33°–36° B. (hot); for hard sugar, to about 33° B. (hot). The syrup is passed through a small Taylor-filter, cooled, and a few lb. of half-congealed sugar of a former boiling are added and thoroughly stirred in. After 10–30 hours, the mass will become so stiff that for common sugar it can be put into barrels and left to harden. For hard sugar, the evaporation is stopped at 33° B., the stirring is not so strong, and is not so often repeated when the partly-coagulated sugar is being added. When the body of the sugar has attained a completely stiff consistency, so that it can only be scooped out with difficulty, it is subjected to pressure in a filter-press or centrifugal machine (see p. 1900).

To make "loaves," the press-cakes or sugar taken from the centrifugal are broken up into small pieces and melted, without adding water. This is done in a kettle over a steam-bath, aided by occasional gentle stirring, in a temperature as low as possible, continued until all lumps have crumbled, but not until the fine parts are dissolved. For 880 lb. of sugar, the operation occupies 3–4 hours. Complete solution of the sugar must be avoided, since those particles which float in the solution favour crystallization. When the mass has attained the proper consistency, it is cast into the moulds; in 2 days, it is entirely solid.

The press-syrup can either be mixed with such syrup as contains a large amount of dextrine, and sold as such, or boiled and worked over again so as to make a second product of press-cakes. To this end, it is evaporated to 36°–37° B. (hot), cooled off and coagulated as usual, and pressed out. The press-cakes thus obtained are inferior, and it is best to dispose of the press-syrups as such.

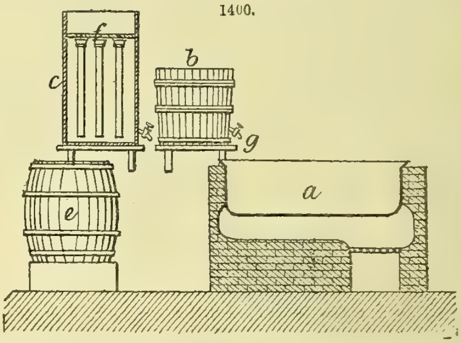
To obtain a product of the whitest possible colour, the application of sulphurous acid is resorted to. After half the chalk has been applied in the neutralization, 3–4 lb. of dry or 11 lb. of liquid sulphite of lime are added, continuing the boiling for 10 minutes, and then adding the rest of the chalk. It is imperative to carry out the process with great cleanliness, and to use no water which contains hygroscopic ingredients.

In Anthon's method for producing 3–4 cwt. of starch-sugar per 24 hours, the ingredients for a boiling are:—

370 lb. of air-dry starch.
11 „ of sulphuric acid of 66° B.
3·70 „ of bone-black.
2·46–3·70 lb. of pure lime.
4·95 lb. of prepared chalk.

The apparatus is very simple, and is represented in Fig. 1400: *a* is the pan; *b*, a vat of about 8½ bush. capacity, with a wooden spigot *g* at the bottom; *c*, a Taylor-filter in a case 4 ft. high and 2 ft. wide and deep, arranged for the reception of 9 bags, each about 2½ ft. in length, and 6–7 in. diam. when filled, and set up so that the thin liquor can be drawn off by a small gutter into *e*. The bags are made of grey linen of prime quality and uniform weft, and are fastened over the funnels *f* with strong cord.

1400.



Capillair-syrup and -sugar.—Some few establishments have furnished quite recently a water-clear syrup, which, in a very condensed state, is known in the market as "capillair-syrup," and is extensively used by confectioners and others in the United States. The mode of producing it is as follows:—After the usual boiling and neutralization, the clear, thin liquor of 16°–20° B. is concentrated in a vacuum-pan to 30° B. (boiling hot). The vacuum-pan is of copper, because by this process the gypsum deposits itself on the copper pipes as firmly as stone, and the pipes have to be frequently cleaned by the aid of hydrochloric acid.

If the temperature can be maintained at 57½°–63¾° (145½°–146¾° F.), the syrup will remain of a lighter colour, as also with rapid evaporation. Since the gypsum never completely separates from this heavy syrup, filter-presses are used. Thus the clarifying is much accelerated, and the thin syrup issues from the filter-presses free from gypsum, and entirely clear. It is directly pumped into the reservoir, thence to the bone-black filter, and is then drawn into the vacuum-pan, and evaporated at 56½°–62½° (133¾°–144½° F.). If the syrup is for exportation, the concentration is carried to 44° B. at 61° (142° F.). The evaporation goes on very quickly, since the syrup already possesses a consistency of 28°–30° B. It has to be filled into the casks while yet lukewarm. If it cools off entirely, it will not run out of the vats at all.

The perfectly white and finest quality of starch-sugar, which also passes through the bone-black filters, is known as "capillair grape-sugar," and is manipulated in a similar way, with this difference, that the syrup at the last stage is condensed to 44°–45° B., while for the production of sugar, the process of evaporating must be stopped as soon as the syrup has reached the consistency of 40°–41° B. This sugar has been mostly packed in cases of 1 cwt.; but more recently it is cast into blocks and loaves, which are afterwards grated, and the sugar packed in bags. This method of packing in bags is more practical and advantageous than in boxes, since the sugar adheres to the wood of the boxes, and much of it is lost.

Granulated Starch-sugar.—The manufacture of granulated starch-sugar was introduced by Fouchard, at Neuilly, France. The transformation of the starch into sugar is accomplished in the ordinary manner, but at an increased temperature and pressure, as a great amount of dextrine would hinder the granulation of the sugar.

The liquor, saturated with lime, is run through a bone-black filter, to impart to it the colour of a nice clear "covering" sugar. The filtered liquor is evaporated in summer to 30° B., in winter to 28° B. (boiling), and run into capacious clearing-tanks, where the greater part of the gypsum settles; the tanks are in a cool place, or the cooling is accelerated by the use of worms in which cold water circulates, so as to avoid fermentation. After the lapse of 24–30 hours, the syrup is cool and clear, and is then placed in vertical barrels, left open above, and whose bottoms are perforated with small holes, thus forming a sieve-bottom. During the process of crystallization, these openings are kept closed with small wooden pegs or taps. The barrels stand on a framework over a lead-lined gutter. In 10–12 days, crystallization begins by the formation of small accumulations in the syrup, which gradually increase. As soon as the syrup is about ⅔ filled with crystals, the holes in the bottom of the barrels are opened, draining off the molasses, while the soft crystalline accumulations remain in the barrels.

As soon as the draining appears to be finished, this is perfected by placing the barrels in an inclined position. The molasses thus obtained is again boiled in sulphuric-acid water, to transform the dextrine present into sugar. The granulated sugar is then placed on gypsum slabs to the thickness of 4 in., and dried at 22°–25° (71½°–77° F.). By increasing the temperature, the crystals would melt and stick together. This lump formation cannot be entirely avoided. If the lower part of the layer begins to get dry and white, it is turned. In 3–4 days, the sugar becomes perfectly dry, and is then, for the purpose of an even separation, rubbed through a sieve, and the lumps which do not pass are ground between a pair of porcupine-rollers. Usually the sugar is again spread on gypsum slabs.

Uses of Starch-sugar and Glucoses.—These products are used chiefly for brewing, for the manufacture of table-syrups and candies, as food for bees, and for making artificial honey. All soft candies and taffies, and a large proportion of stick candies and caramels, are made of glucose-syrup. Very often a little cane-sugar is mixed, in order to give a sweeter taste to the candies, but the amount of this is made as small as possible. A very large percentage of all the starch-sugar made is used for the manufacture of table-syrups. Some kind of cane-sugar syrup is added until the tint reaches a certain standard. The amount of cane-sugar syrup required varies from 3 to 10 per cent., according to circumstances. These syrups are graded A, B, C, &c., the tint growing deeper with each succeeding letter. Small quantities of glucose-syrup are used by vinegar-makers, tobacconists, wine-makers, distillers, mucilage-makers, and perhaps for some other purposes.

The solid sugar is also used for many of the purposes enumerated, but chiefly for the adulteration of other sugars. When it is reduced to fine powder, it can be mixed with cane-sugar in any proportions, without altering its appearance. Since starch-sugar costs less than half the price of cane-sugar, this adulteration proves immensely profitable.

The cost of manufacture is about ½*d.* a lb. Some 26–32 lb. are made from a bushel of corn. It is sold by manufacturers at 1½*d.*–2*d.* a lb.

Sugar-refining (*Raffinage du Sucre*; Ger., *Zuckersiederei*).—Very large quantities of sugar are consumed in their "raw" state, just as they reach the home markets from the plantations; but others are so impure as to be unfit for immediate use. The purification of these latter, and the preparation of fine sugars from the low grades, is the work of the refiner. The estimation of the impurities, and the qualities of the various kinds of sugar, will be found detailed under the section on Analysis. The appended analyses, however, present a comparison of the relative mineral impurities in cane- and beet-sugars as regards bases, the phosphoric and carbonic anhydrides and the chlorine having been displaced by the sulphuric acid employed in the analysis, and the results being calculated on the ash. It will be noticed that cane-sugar ash contains larger proportions of lime, magnesia, ferric oxide, and sand, than beet-sugar; while potash and soda largely predominate in the latter:—

	Cane-sugar Ash.	Beet-sugar Ash.
Potash	28·79	34·19
Soda	0·87	11·12
Lime	8·83	3·60
Magnesia	2·73	0·16
Ferric oxide and alumina	6·90	0·28
Sulphuric anhydride	43·65	48·85
Sand and silica	8·29	1·78
	100·06	99·98

In addition to these, there are glucose, low sugars, and organic matters of other kinds, which it is desirable to remove.

Synopsis of Operations.—No two refiners follow precisely the same process in all details; and as it would cause much confusion to introduce the deviations as they occur, the preferable plan will be to commence with a general account, and to supplement this with particulars of special methods.

In planning a refinery, it is very desirable, in fact almost absolutely necessary, to arrange the various plant and machinery so as to allow the liquor so far as possible to descend by gravitation during the different processes, and so avoid pumping. For this reason, refineries are built in blocks seven or eight stories high, and all the raw sugars to be refined are hoisted by crane to the top of the house, the refined article being discharged at the bottom.

The refinery must have an ample supply of good water, for melting the sugar, washing bags, working vacuum-pans, washing char, &c.; cleanliness in a refinery is a matter of first importance, and a limited supply of water is one of the greatest drawbacks which a refiner can be subjected to, as it not only prevents him from recovering the whole of his sugar, but, if the water is bad, renders him liable to a multitude of complications, the causes of which he is at a loss to account for.

The first operation after the raw sugar has been hoisted to the top story of the house, is to break open the bags or hhds. In the case of hhds., the sugar is tipped directly on to the floor, the hhds. are scraped, passed into a steam chamber, steamed, and washed with hot water, so as to remove the whole of the sugar. The contents of the bags are tipped directly on to the mixing-floor, or into the dissolving-pans, and the bags are steamed and washed. The steaming and washing of bags is of some importance, as bags containing 80–100 lb. of sugar will frequently retain 1–2 lb. of raw sugar, which is only recovered by steaming and washing; the water used in washing should not be too hot, neither should the bags be steeped for too long a time, more especially in the case of mat or grass bags from China and the East, as they frequently contain notable quantities of alkaline salts and colouring matters, which are readily dissolved by treatment with boiling water, rendering the refiner's work more difficult, and lessening the quantity of refined sugar produced. The sweet waters from bag- and cask-washing are run into the blow-up pan before they have time to ferment.

The blow-up is set immediately below the mixing-floor, and is a cast- or wrought-iron tank, provided with a vertical shaft and mixer, as well as one or two copper coils through which live steam can be introduced. It is capable of holding 7–10 tons of sugar, which when melted to 28°–30° B. will measure 3000–4500 gal.; the steam coils are covered either with sweet water from bag-washing, or fresh water. Steam is turned on, and the raw sugar is either shovelled in from the mixing-floor above, or delivered direct from the bags. In working, it is customary to run in water up to a certain mark on the blow-up; the water of condensation produced by the live steam adds further to this quantity, and probably fills the blow-up something less than half full. Mixed or analyzed sugar is then filled in gradually until the blow-up is full to within 4–6 in. of the top, steam blowing in during the whole time. When the sugar is thoroughly melted, the sp. gr. is taken with a Baumé hydrometer, and should be 25°–27° B., which will equal 27°–30° when cold. The quantity of sugar melted at one time varies from 5 to 8 tons; it of course greatly depends upon the quality of the raw sugar used; a much larger quantity of low-class sugar is required to fill the blow-up than is necessary when good crystallized sugars are used. The time occupied in melting this quantity of sugar is about ½ hour, and it is necessary in the case of very low sugars to partially neutralize the acidity with a few buckets of lime-water thrown into the blow-up during the operation of melting. This causes a precipitation of some of the soluble organic impurities, which are thrown down in brown flocks, and removed in the subsequent stages of the process. It is also necessary during this operation to remove by skimming the pieces of wood, cane, grass bags, and other miscellaneous articles which are present in low sugar, and which rise to the surface along with a dirty scum. The liquor thus prepared is run first through a wire strainer which removes hairs, sacking, and fibres, and any pieces of matting which may have escaped the operation of skimming.

The liquor runs from this strainer (or in some cases the valve at the bottom of the blow-up delivers the liquor directly into the bag-filters, without passing through the wire strainer) into the bag-filter box.

Bag-filters.—Those generally in use are Taylor's, and have already been described on p. 1889. Refineries are always provided with a large number of boxes, each box holding 400–500 bags, and placed immediately below the blow-up pans. The filtration through these is a tedious operation, on account of the exceedingly slimy nature of the insoluble organic matter, which though small in amount, is of such an objectionable character as to coat the inside of the bags with a tenacious deposit not more than $\frac{1}{16}$–$\frac{1}{8}$ in. thick, which prevents the liquor finding its way through; for this reason, the quantity of liquor filtered through a box of 400 bags is not much more than 2000–3000 gal., or say about 5 tons of sugar per day. Of course this amount depends greatly upon the quality of the raw sugar, and the amount and nature of the insoluble organic matter which it contains. Previous to starting the filter, it is necessary to steam out the box containing the bags, so as not to cool the first portion of the liquor running through. After the filter has finished working, the upper part is filled up with boiling water, and allowed to stand some hours, until the whole of the water has filtered through the bags, removing with it the greater part of the sugar; the bags are then steamed, rewashed if necessary, taken from the box, and dried ready for further operations.

The liquor as it runs from the bag-filters is dark in colour, but clear and bright, and it now remains to remove from it the whole of the colouring matter and soluble organic impurities, which is done by means of filtration through animal charcoal. The action of the charcoal in removing the colouring matter is not clearly understood. It is sufficient to say that almost any sugar, no matter how dark in colour, can be rendered as clear as water by using sufficient bone-black in a finely divided condition, taking care that the liquor when filtered is as nearly boiling as possible. The liquor from the Taylor's filter is received or pumped into tanks placed above the charcoal cisterns, provided with steam-coils in order to heat up the liquor previous to passing into the char.

Charcoal cisterns.—These are now made of cast-iron, and in large refineries are capable of holding 30–40 tons of char; they are enclosed at the top, the charcoal being packed tightly, and the liquor being forced through under 3–7 lb. pressure (see pp. 1851–3). The cisterns are packed tightly with well-burnt dry char, and the hot liquor is run in at the top, the cock at the bottom of the cistern being open so as to allow the confined air to escape. When the cistern is full of liquor, it is allowed to stand for 3–4 hours "to settle." At the expiration of this time, the cock drawing from the bottom, on the upright pipe which leads the fine liquor above the surface of the char on the outside of the cistern, is opened, and the stream of liquor, which is perfectly clear, is adjusted so that the decolorizing power of the char is not too rapidly spent; or in other words, the liquor must be left a sufficient time in contact with the char to allow the latter to act upon the organic impurities. As a rule, all the discharge-pipes from the cisterns are brought into one room, and arranged over a number of gutters communicating with an equal number of tanks to receive the fine liquor. At first, no colour can be detected in the liquor, but after a while, the time depending upon the purity of the sugar operated upon, and the quality of the char, the liquor begins to assume a yellowish tinge. Previous to this, however, the attendant has altered the course of the liquor, and it is now flowing into another tank, the first portion being used for making the finest refined article, either loaves or crystals; the second portion, received in a separate tank, is used for making crystal-sugars, which have not a similar degree of whiteness and brilliancy. The cistern is worked until the decolorizing power of the char is exhausted, or until the liquor running away is only slightly superior in colour to the liquor as delivered into the cistern. Occasionally the liquors having a slight tinge of colour are reheated and used to "settle" a fresh cistern of revivified char, following with the liquor from the bag-filters; by this means, a larger quantity of liquor of 1st quality is obtained at a comparatively small cost, as the amount of colouring matter which these liquors possess is not sufficient to materially reduce the decolorizing power of the animal charcoal.

As a rule, charcoal cisterns are always "settled" or started with fairly good liquor, which is followed by raw sugar liquors, or syrups. If the charcoal is not thoroughly exhausted after the syrup, molasses (or more correctly syrup from last boiling) is run through the cistern.

It is necessary so soon as the charcoal is exhausted to wash it free from sugar. Boiling water is run on to the char, which carries before it in its downward passage the sugar liquor. The washings of the char are run into the syrup-tanks so long as they stand at or above 18° B.; below this the liquid gradually getting weaker and weaker is run into a separate tank, the washing being continued until the liquor marks 1°–2° B. At this stage, the bottom cock on the cistern is opened, and sufficient boiling water is run through the char to thoroughly wash it free from traces of sugar and organic impurities; the cistern is then emptied, and the char is dried and revivified. The weak waters used for washing, and marking 7°–15° B., can be used for washing off another cistern, or in the blow-up for melting a fresh quantity of raw sugar. It is important that they should be used quickly, as otherwise they are very liable to undergo fermentation. The quantity of charcoal used depends entirely upon the quality of the raw sugar passing through; in general, ¾–1¼ tons are required per ton of sugar, and, with low Manilas, even more than this. Charcoal attains its greatest power of decolorizing syrups after being 4–6 months in use; each revivification seems to greatly increase its absorptive powers, until a certain point is reached, after which it gradually deteriorates, and requires mixing with a proportion of new charcoal in order to keep up its action.

Revivification of the Charcoal.—(Several forms of revivifying-kiln have been described under Beet-sugar, pp. 1853–4.)

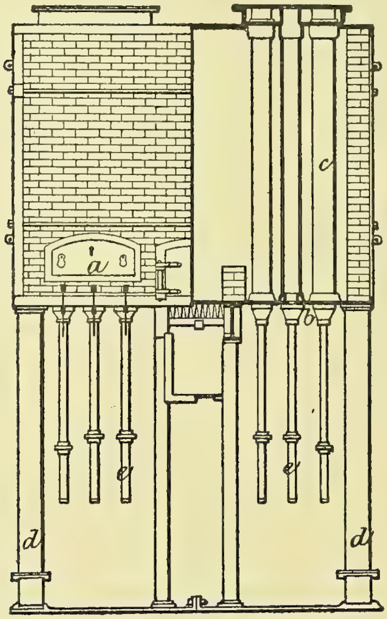
The practice of washing the char, after its removal from the cylinders, with hydrochloric acid, with the object of taking out salts of lime absorbed from low sugars, appears to be rarely adopted in this country. But when the washing with hot water is performed too slowly, the weak saccharine solution which results is apt to acetify, and this produces a similar result, which is recognized by the solution being opaque and milky when it is run off. This acetification is more likely to occur when the char has been in use for too long a time, and more readily in old than in new char. New char will often give off liquors smelling of sulphuretted hydrogen when the sugar refined is acid. Acetification will also occur under conditions which are little understood, but over which refiners have no power of control. Also when imperfectly washed char, which after draining may still retain sweet water, is allowed to stand for some indefinite time before being reburned, it is apt to ferment and acetify. This fermentation is sometimes regarded as a benefit to the char, serving to open it by removing matters within its pores which mere washing will not get rid of.

The principal forms of kiln used in this country are as follows:—

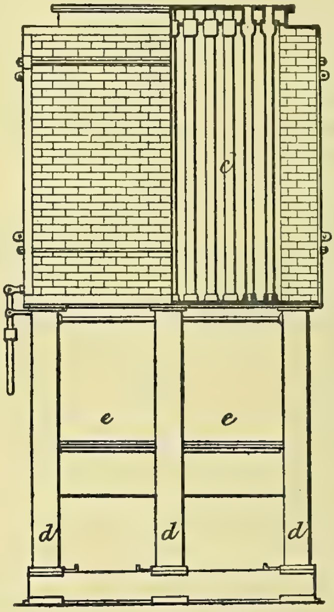
The pipe or tubular kiln, made by McLean and Angus, Greenock, is illustrated in Figs. 1401–3. Each reburner consists of a series of 64 iron pipes *c*, arranged in two banks or groups of 32 each on either side of a central fire, the whole being raised upon iron columns *d*, which, being hollow, are made to serve as flues. The flame from the fire plays among these pipes, and is regulated by appropriate dampers. In the brickwork enclosing the pipes, opposite each group, is an iron plate *a*, with an arrangement for viewing the several rows of pipes. Beneath each of the six rows into which the pipes are distributed, is a narrow iron box *e*, freely exposed to the air, and serving as a cooler for the reburned char. A slide-valve at *b* permits the discharge into the cooler of the lower portion of the contents of the pipes from time to time, the coolers being emptied below upon the floor, or into vessels run in under them. The top of the kiln where the open ends of the pipes appear forms a platform near the roof of the building where the apparatus stands. Upon this platform, the damp char is heaped up, and there undergoes some preliminary drying by evaporation. Whenever a cooler is refilled, the char sinks commensurately in the pipes corresponding to it, and a workman upon the platform at once with the shovel refills the pipes to the top. Whatever vapours are evolved by the reburning escape from the top of the char-pipes, and pass out of the building through openings in the roof.

The Buchanan & Vickess reburner is a modification of the preceding, which, while it is said to burn the char more equably, provides for the collection of the vapours that are given off. Fig. 1404 shows those parts of the apparatus which it is necessary to describe. The tubes *a* are arranged much in the same way as in the ordinary reburner. Each pipe, however, is double, consisting of a wide external tube *b*, and a narrower internal tube *c*, and the char, falling from a platform above, occupies the space *d* between the two tubes. The internal tube is provided with openings *f* in its circumference at definite intervals, and these openings are protected from the ingress of char by a louvre-like projecting plate, inclined downwards at an angle, from the part of the tube immediately above them. The vapours given off during the reburning pass through these openings into the interior of the tube *c*, which opens above, together with other tubes in the same row, into a horizontal channel or flue *g*, which conducts the vapours away. The outer tube is made to revolve in its longitudinal axis around the inner one. There are also revolving coolers *h* below.

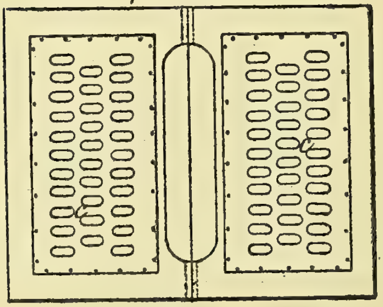
1401.



1402.



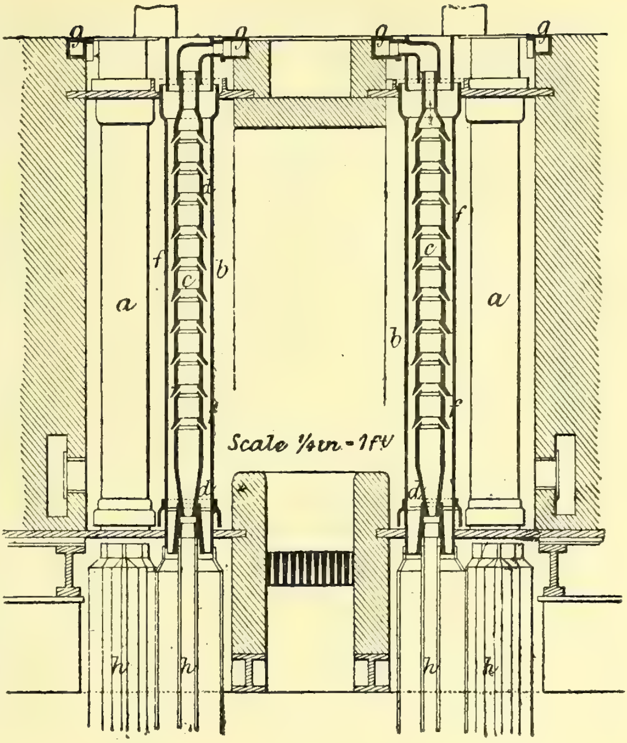
Scale 1/16 in = 1 ft



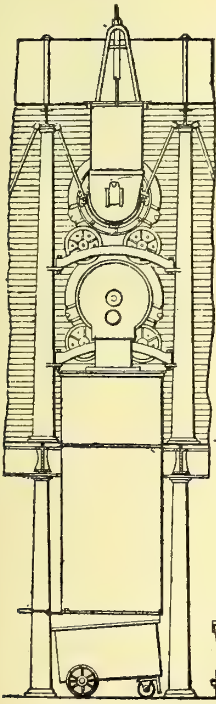
1403.

Of revolving cylinders, perhaps the best is Brinjes', shown in Figs. 1405–8. Fig. 1405 represents a front elevation of the apparatus complete; Fig. 1406, a sectional elevation; Fig. 1407, a back elevation; and Fig. 1408, a sectional plan. In a brick setting, are two horizontal retorts, each of which receives a circular reciprocating or alternating motion of nearly one entire revolution on its longitudinal axis. The upper retort acts as a drying-chamber for preparing the charcoal for the revivification which takes place in the lower retort; and it is contained in a separate brick chamber of its own, which is situated immediately above the roof of the furnace, the heat from which, after circulating round the lower retort, enters the upper chamber through openings left for that purpose in the roof of the furnace, and then acts upon the upper retort before passing off to the chimney. The two retorts are provided with a series of internal flanges at intervals of about 6–8 in., and ledges are formed between the flanges for carrying up the charcoal as the retorts reciprocate. An opening is made through each flange, and all these openings are disposed in a line with each other. To cause the charcoal to travel continuously along the retorts during the process of revivifying, an angled projection, somewhat after the form of a 3-sided pyramid, is cast inside the cylinder in each of the intervals or spaces between the several internal rings or flanges, and exactly in the centre line of the openings in these flanges. The two opposite sides of these projections present reverse angles, both of which direct the charcoal into the next space on the partial rotation of the retort. The upper retort is driven direct by a mangle-wheel and pinion arrangement; and this motion is transmitted to the lower retort by means of an endless chain, suspended from the rear end of the upper retort, and passing under the corresponding end of the lower

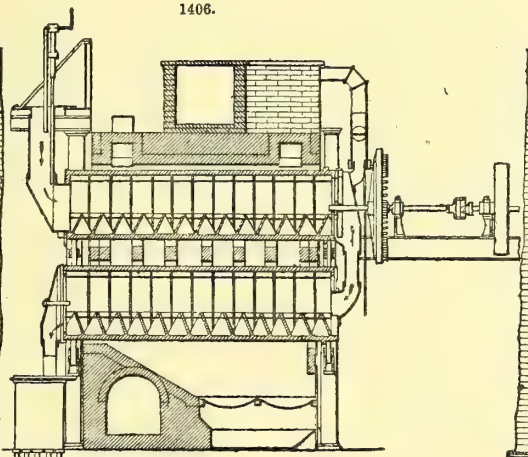
1404.



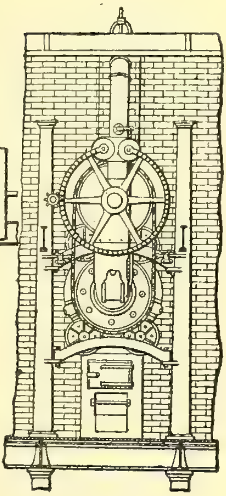
1405.

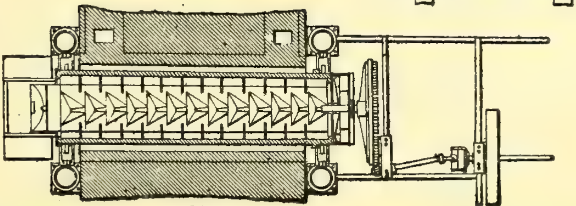


1406.



1407.





1408.

retort. Both ends of the retorts are supported upon anti-friction pulleys, carried in the transverse framing, bolted to the main supporting column. The feeding hopper opens to a flue, from which the charcoal is shovelled when being supplied to the retorts, the feed being nicely adjusted by means of the sliding-door, worked by a winch-handle and screw-spindle. A sliding door, covering an opening in the inclined side of the hopper, is for the purpose of inspecting the interior of the retort; a spy-hole is also provided in the stationary front cover of the lower retort. The upper retort discharges its contents into a conduit, which conducts it to the lower retort, after traversing which, it is discharged down a pipe into an enclosed receiver. From this receiver, it passes through the cooler, which consists of a number of long narrow passages, placed side by side, and having intervening air-spaces between them for the more effectual cooling. By the time the charcoal has traversed these coolers, it is sufficiently cool to be exposed to the action of the atmosphere, and is discharged into a small truck. The vapours which are evolved during the reburning are carried off by a pipe, provided with a throttle-valve, communicating with the chimney. The entire arrangement is supported upon strong iron girders, resting upon columns in the basement.

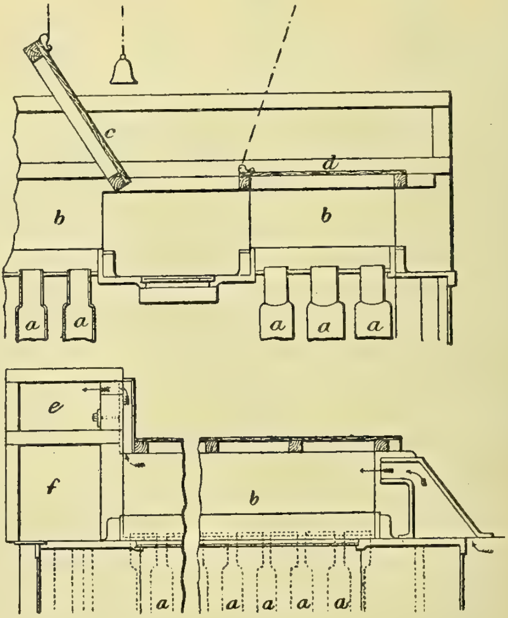
When the revivified char is cold, it is sifted, and the dust is sent away to the manure-makers, as is also the finally spent char from the filters (see p. 1266).

Under the most favourable circumstances, the vapour that issues from char in process of revivifying has usually a sweetish and slightly empyreumatic odour, but is never overpowering, though sometimes sufficiently pronounced to be very disagreeable. Whatever ill odours may attach to the vapours must depend upon the evolution of sulphuretted hydrogen, and the products of decomposition of the organic matters taken out of the raw sugar in its passage through the charcoal. The remedies obviously consist:—

1. In the thorough washing of the char before reburning, so as to remove from it as much as possible those matters which by their burning give rise to offensive effluvia. At James Duncan's refinery, pressure-cisterns are in use to hasten the passage of the syrup through the char, and the washings, similarly hastened, are continued for 6–7 hours after the last of the sweet water has been removed. The time that elapses from charging a charcoal cistern to the char again going to the reburner is not more than 35 hours. Fermentation is thus altogether prevented.

2. Means should be adopted for collecting and disposing inoffensively of the vapours proceeding from the reburning. When Brinjes' reburner is in use, the vapours are collected as a matter of course, being conducted first into a long brick chamber or flue 3 ft. sq. internally, and thence into a chimney-shaft at a point below that at which the furnace-flue enters; this shaft discharges them at a sufficient elevation to prevent any nuisance. At other works, the vapours are discharged at once into a tall chimney-shaft, without occasioning nuisance. Should it be thought necessary, means of condensation might readily be added to this apparatus. There may be some difficulty in collecting the vapours proceeding from pipe-kilns, but it is nevertheless practicable. At Duncan's works, a space *b* above each stack of pipe-kilns *a* is boxed with a wooden cover *c d*; hot air is conducted into this space from the fire by means of an appropriate flue *e f* at one end, and passes out at the other end, carrying the vapours with it into a chimney. This arrangement is shown in Fig. 1409. At one part of these works is a common horizontal flue to receive all the vapours from a row of reburners; and, should it be requisite, the vapours might very readily be condensed. After condensation of all that is condensable, the remainder might be passed through a fire. One of the advantages of Buchanan's reburner is that provision is made for the collection of the vapours.

1409.



Boiling.—The next operation is the boiling of the decolorized liquor; this is performed in vacuum-pans already described (pp. 1854–7), the method of boiling not essentially differing from that detailed on pp. 1893–5. In the case of crystal sugar, the grain is obtained low down in the pan, the crystals being fed by the admission of fresh liquor; care is taken not to drown the small crystals of sugar already formed, and not to boil so low as to cause fresh crystallization.

Several methods are employed in order to obtain a large grain, such as cutting the charge, i. e. when the pan is quite full, half the sugar is run out, and fresh liquor let in upon the remaining half in the pan, and the pan is boiled full; the crystals in this case are considerably increased in size, as the fresh liquor deposits its sugar on the surface of the crystals remaining in the pan. It is important in boiling for grain to feed the grain often, and with a comparatively small amount of liquor each time; to boil at as low a temperature as possible, with a good vacuum of 26–27½ in.; and to take a proof at least every few minutes, especially when grain is expected and when the crystals are "growing." The proof is carefully examined on a sheet of glass; when the boiling is nearly finished, the "proofs" are almost solid, and the liquid in which the crystals are suspended sets almost immediately on being spread about on the plate of glass. At this stage, it is sometimes customary to increase the temperature some 10°–15°, in order to harden the grain. The *masse-cuite* is quickly let out of the pan into a tank, which is sometimes circular and provided with a mixer and steam-jacket; this arrangement is called a "heater"; from the heater or tank, it is delivered by suitable mechanical appliances to the centrifugals. Numerous mechanical contrivances are in use for delivering the *masse-cuite* from the heater or tank to the centrifugals. Small iron trucks suspended or running on rails, passing under the heater and over the centrifugals, and making a complete circle, are frequently employed; the truck, which is of a convenient size to supply one or two centrifugals, is passed under the heater, the slide-valve is opened, and the truck is filled with *masse-cuite*; this is run over the first centrifugal, a slide-valve is opened at the bottom of the truck, and its contents are delivered into the centrifugal, which has previously been started and is running at a slow speed.

The "heater" is now dispensed with in most refineries, and its place is taken by some less complicated form of apparatus; it is certainly not necessary to provide it with a steam-jacket; the stirrers require powerful machinery to drive them, and it is questionable whether they really fulfil any useful purpose, provided the *masse-cuite* is centrifugalled within a few hours after its leaving the pan. First *masse-cuites* from fine liquor are generally boiled to a high degree of consistency; the amount of water which they contain varies within slight limits, but is generally between 7 and 10 per cent. The colour should be only very slightly yellowish. The yield of crystal sugar from highly-refined *masse-cuites* is from slightly under 50 to perhaps 55 per cent. of the weight of the *masse-cuite*; it rarely runs above the latter figure.

In the case of loaf or cube sugar, the liquor is boiled for small grain, and the *masse-cuite* is run out very stiff, containing not more than 7 per cent. of water. The *masse-cuite* is filled into moulds. In the case of loaf, the loaves are kept in a warm room for some hours, until the sugar is nearly set; the moulds containing the sugar are then elevated to the upper portion of the house, and the sugar is allowed to solidify and liquored with fine liquor at 25°–30° B.; when the requisite degree of whiteness is obtained, as much of the liquor as possible is drawn away by means of suction, and the sugar is dried in ovens, and turned out of the moulds, when it is ready for sale. With cubes, the *masse-cuite* is filled into peculiarly-shaped moulds which fit into a large centrifugal machine; after the sugar has set, the moulds are transferred to the centrifugal machine, washed or liquored in the machine, dried, and packed. The yield of refined sugar by this means is 70–80 per cent. of the weight of the *masse-cuite*; but the extra time and labour required in handling the loaf-sugar does not more than pay for the increased yield by this method, over the 50 per cent. obtained in the mode of making crystal sugar already described.

The Alum Process.—The "alum process" for removing potash, ammonia, and other impurities from saccharine solutions (see also pp. 330–2), is due to James Duncan, and John A. R. and Benjamin E. R. Newlands. Beet-syrups contain a notably large proportion of potash salts, which much retard crystallization. The salts in beet-molasses, according to Dr. Wallace, are:—Chloride of potassium, 18·70 per cent.; sulphate of potash, 4·18; carbonate of potash, 53·80; carbonate of soda, 20·81; carbonate of lime, 0·35; magnesia, 0·27; moisture and loss, 1·99. A sample of French beet-molasses gave 10·86 per cent. of ash, 4·88 being potash. Out of 3·40 per cent. of ash from English beet-syrup, 1·36 is represented by potash. Low-class cane-sugars also contain notable proportions of potash:—Dutch Bastards, 0·33; Guatemala, 0·40; Penang, 0·71; Low Penang, 0·57; Medium Penang, 0·23; Egyptian, 0·63, 0·53, 0·80; Jaggery, 0·49; Clayed Manilla, 0·23; Iloilo Manilla, 0·58 per cent.

The alum process consists of two parts: 1st, precipitation of the potash in the form of alum; 2nd, neutralization of the residual acid liquor by means of lime.

1. Precipitation.—This is accomplished by adding to the cold syrup a solution of sulphate of alumina, sufficient to form an alum with the whole of the potash present. It is convenient to work with syrup at about 38° B., and solution at 27° B.; if the syrup be much over 38° B., the alum cannot easily settle out. The mixture is well stirred for ½–1 hour, and the whole is allowed to

repose for 4–5 hours, until the deposit—which consists of small alum crystals, known as "alum meal"—has completely subsided. The "alum-tank" in which this operation is performed is provided with mechanical stirring-gear. The three principal requisites in order to obtain the best results, and to prevent the formation of uncrystallizable sugar, are:—(1) To work at the lowest temperature; (2) to employ solutions as dense as possible; (3) to perform the whole operation as quickly as is consistent with separation of the alum.

The amount of potash present in syrups is generally equal to $\frac{2}{5}$ of the ash, determined in the usual way (see p. 1946). Every 1 part of potash requires for conversion into alum about $9\frac{1}{2}$ parts of sulphate of alumina, of which, $2\frac{1}{2}$ parts are required to convert the potash into sulphate, and the remaining 7 to combine with the sulphate of potash, so as to form alum. If the liquor contains free or combined sulphuric acid, or if the solution of sulphate of alumina contains any free sulphuric acid, the $2\frac{1}{4}$ parts of sulphate of alumina required to convert the potash into sulphate may be partly or entirely dispensed with. For practical purposes, it suffices to determine the percentage of ash, to assume $\frac{2}{5}$ of this to be potash, then to multiply the percentage of potash by 9·5, which gives the dry sulphate of alumina, and, lastly, to ascertain the amount of solution corrresponding to this.

2. Neutralization.—The alum-tank is provided with several taps, at different heights; when the alum has well settled down, the clear acid liquor is run off, by means of these taps, into a "liming-tank" placed on a lower level, and also provided with mechanical stirring-gear. As soon as the acid liquor has been thus decanted into the liming-tank, a little finely-divided chalk, previously made into a paste with water, is added, so as to produce a slight effervescence. Milk of lime is then added at frequent intervals, until the froth has nearly, but not entirely, disappeared: the gradual abatement of the froth indicates when the neutralization is nearly complete. This operation takes 1–2 hours. The point at which the neutralization is practically complete may be known by:—(1) The absence of any large amount of froth; (2) the absence of any taste of aluminous compounds; (3) the liquor should give only a *dull*-red tinge to blue litmus-paper. When the neutralization is thus practically complete, the treated liquor is subjected to the same routine as ordinary sugar-solutions in a refinery: it is heated in the blow-ups to 65° (150° F.), but not higher, then passed through filter-presses, and through char, and boiled down in the vacuum-pan.

To wash and dry the precipitated alum, it is convenient to employ a small centrifugal machine. After once "machining" for a few minutes, a little water being added as usual during the operation, the alum appears white and dry, but still retains a small amount of syrup. It is then mixed with some cold water, and machined a second time, after which it is free from sugar, and fit for sale.

The following analyses show the effect of the process on beet-syrup treated on a large scale:—

	Beet-Syrup.	After Treatment, and before Char.	After Treatment, and after Char.
Sugar..	60·18	40·54	41·60
Ash	3·61	1·33	0·47
Water, &c...	36·21	58·13	57·93
	100·00	100·00	100·00

The advantages of the process are:—(1) The removal of potash and ammonia from syrups without much dilution; (2) the removal of much colouring and albuminous matters; (3) considerable improvement in flavour and odour; (4) the alum produced is nearly equal in value to the sulphate of alumina used, so that the expense of the process is not great; (5) the plant required is of the simplest description, the cost of labour is small, and the operations are continuous and rapid.

The process has been in constant operation during several years at the sugar-refinery of James Duncan, Clyde Wharf, Victoria Dock, London, where the syrup from many thousands of tons of sugar have been treated with excellent results, several hundred tons of potash-alum of good quality being during the same time produced, and sold at a fair market-price. Licenses to work the process have been taken by nine of the principal refiners of the United Kingdom, and others have been granted to several refiners in Holland, Belgium, and the United States.

The foregoing description applies to the process as actually conducted at the Clyde Wharf Refinery; various alterations are advantageous under particular circumstances.

Strontium.—Strontium is a powerful base for extracting sugar in the refinery, as it combines with 3 equivalents of sugar. Native strontianite, containing 90–95 per cent. of pure carbonate of strontium, is said to be now largely employed in Continental sugar-refineries. This has hitherto been obtainable only with difficulty, but recently in Westphalia it has been worked to a great depth in mines, and a supply of many thousand tons per annum is said to have been secured.

Oxalic Acid.—C. H. Gill has proposed to effect the removal of potash from saccharine solutions by the addition of oxalic acid, in the state of powder, or of hot or cold solution, in quantity sufficient to form oxalate, binoxalate, or quadroxalate of potash, or a mixture of these, which, being comparatively little soluble, crystallize out more or less completely. To cool syrup at 26°–35° B., contained in a suitable vessel provided with means of stirring its contents, is added a quantity of oxalic acid equal to 63 (or even up to 252 lb.) of the crystallized acid for each 39 lb. of potassium present in the syrup operated on. The mixture is stirred till the reaction is complete (say, 1 hour), and then either allowed to rest till the crystalline oxalates of potash have settled to the bottom of the liquid, or filtered. The clear syrup is drawn off into another vessel, also provided with stirring gear, and together with the syrup separated from the magma of crystalline oxalates, neutralized by addition of milk of lime, or whiting stirred up in water. The neutral or nearly neutral syrup is then boiled, bag-filtered, and treated in the usual way.

The advantages of this process are:—That the removal of a portion of the potash allows the recovery of a quantity of crystallizable sugar, which would otherwise go to form molasses; that on neutralization by lime or chalk, a very large proportion of the iron present is precipitated and removed; that when soda salts are present in large quantities, a portion of the soda will be precipitated as oxalate with the oxalates of potash, and will be removed from the solution with them; that saccharine solutions containing a very large proportion of potash can be operated upon, since the precipitate formed on neutralizing the acid liquid separated from the oxalates of potash places no difficulties in the way of filtration.

The expense of carrying out the process is reduced to a comparatively small amount, either by selling the oxalate of potash obtained, as such, or by recovering the oxalic acid for re-employment, and selling the potash separated at the same time. For the latter purpose, the oxalate of potash may be dissolved in hot water and decomposed by a sufficiency of lime (caustic, carbonate, or chloride), and the insoluble oxalate of lime is separated from the solution of potash simultaneously produced. This oxalate of lime, together with that obtained on neutralizing the acid saccharine liquor separated from the original precipitate of oxalates of potash, can then be decomposed by sulphuric acid, and the oxalic acid thereby brought into solution. Afterwards, the oxalic acid is crystallized. The liquids containing the potash in solution can likewise be evaporated and brought into marketable form. It must not be forgotten, however, that oxalic acid is a powerful poison; and if a small quantity were from any cause allowed to remain in the refined sugar, the consequences would be most serious.

Tannin.—Gill and Martineau propose to use tannin for separating from sugar-solutions iron and other bodies, such as albumen, which are thus precipitated. For this purpose, an excess of tannin is added to the sugar-solutions, and subsequently removed by the addition of alumina. The alumina may either be precipitated in the solution, or may have been previously precipitated. The sugar-solution subjected to this process may be crude juice, or a solution of raw sugar, or drained syrups. By preference, the sugar-solution is boiled with the tannin, and then alumina which has been precipitated from a solution of alumina by means of whiting or carbonate of lime is added. After boiling, the solution is passed through bag-filters and animal charcoal, and evaporated and crystallized in the usual way.

Chloride of Sulphur.—In Eastes' process, the raw or low-quality sugar is dissolved, clarified, and tempered with 2–8 oz. of chloride of sulphur to 100 gal. of liquor, or the same proportion of any compound of chlorine of sulphur, or sulphide of lime, or chloralum, according to the quantity of albuminous matter contained in the liquor. After clarification, the liquor is allowed to subside, and passed through the vacuum-pan in the ordinary way. For extracting the crystallizable matter from molasses, the latter is heated and tempered as follows:—If recently-made molasses are treated, one of the agents simply is used; in the case of molasses that has been made for a considerable time, and contains free acid, sufficient alkali is used in addition.

Alcohol.—Duncan and Newlands propose to treat raw or low-class sugar by alcohol (ethyl or methyl alcohol, or methylated spirit). The sugar, containing more or less uncrystallizable sugar, is agitated in a close vessel for about ¼ hour, with a considerable quantity of alcohol, as near the boiling-point as possible. About 3 gal. of alcohol to 10 lb. of sugar is usually sufficient. The alcoholic solution is then separated by decantation, filtration, or a closed centrifugal machine, and allowed to cool, when the greater part of the uncrystallizable sugar and other matters are deposited. The alcoholic solution is next separated from this deposit, in a similar manner, and is then reheated and re-used for the purification. After the alcohol has thus been alternately heated, used for washing sugar, and cooled several times, it is distilled, to separate it from water and other impurities. The sugar deprived of its impurities is heated with or without water in a still, so long as any adhering alcohol distils over.

The principal advantage of this mode of employing alcohol over those previously proposed, is that by alternately heating and cooling, the same alcohol can be made to serve several times without distillation, instead of its having to be distilled after every operation.

Sucrate of Lime Process.—This process, which has been successfully worked both for refining raw cane- and beet-sugars and for defecating cane-juice, was invented about 1865 by Boivin et Loiseau, of Paris. Successive improvements have since been made by the original patentee and others. The process effects great purification of sugar-solutions by means of a compound of sugar and lime, denominated "sucrate of hydrocarbonate of lime," formed in syrups which have been treated with calcium hydrate and submitted to the action of carbonic acid gas; but careful manipulation is necessary to ensure the desired result. When the compound is treated as will be afterwards described, it produces a very flocculent precipitate, which, in subsiding, carries with it, mechanically or in chemical combination, most of the colouring matters and other impurities present in the juice or unrefined sugar. The process depends mainly upon this peculiar decomposition of the sucrate of hydrocarbonate of lime, and on the difference in solubility of the several sucrates of lime in saccharine solutions.

Chemists have long known that sugar is capable of acting the part of a weak acid and combining with bases. With calcium hydrate, it forms a series of compounds known as calcium sucrates, all of which when suspended in water are decomposed by carbonic acid gas into calcium carbonate and sugar. When a proportion of calcium sucrate (say 5–10 per cent.) is formed in a fairly concentrated solution of cane-sugar, and partly but not entirely decomposed by passing carbonic acid gas, a compound is formed containing calcium hydrate, sucric acid, and carbonic acid chemically combined. This compound is the sucrate of hydrocarbonate of lime of Boivin et Loiseau; but if the current of gas is continued too long, this compound is decomposed, and calcium carbonate and sugar result.

The following table gives the density of lime sucrate solutions:—

Per cent. of Sugar.	Density of Sugar Solutions.	Density when Saturated with CaO.	The Sucrate Solution contains in 100 parts:	
			CaO.	Sugar.
2·5	1·018	1·026	15·3	84·7
5·0	1·027	1·040	16·9	83·1
10·0	1·036	1·053	18·1	81·9
12·5	1·044	1·067	18·3	81·7
15·0	1·052	1·080	18·5	81·5
17·5	1·060	1·092	18·7	81·3
20·0	1·068	1·104	18·8	81·2
22·5	1·075	1·116	19·3	80·7
25·0	1·082	1·128	19·8	80·2
27·5	1·089	1·139	19·9	80·1
30·0	1·096	1·148	20·1	79·9
32·5	1·103	1·159	20·3	79·7
35·0	1·110	1·166	20·5	79·5
37·5	1·116	1·175	20·8	79·2
40·0	1·122	1·179	21·0	79·0

When concentrated, this sucrate of hydrocarbonate of lime is a thick gelatinous mass (semi-solid), which when cold is sufficiently firm to be cut with a knife like jelly, but not sufficiently solid to prevent its being conveyed through pipes. Its chemical characteristics are as follows:—Treated by excess of carbonic acid gas, it is readily decomposed into calcium carbonate and sugar; heated above 100° (212° F.), it darkens in colour owing to the formation of caramel; cautiously dried below 100° (212° F.), it forms a whitish friable powder; boiled with impure saccharine liquors, it combines with a large proportion of the impurities present, and is partly decomposed. There are at least 3 chemical compounds closely resembling it, the main difference being in the proportion of sucric acid which has been replaced by carbonic acid. But the appearance of the 3 compounds when moist is not materially different.

The process of refining by means of this compound has been carried on for some years in a refinery in Paris, and in one or two in England; but its use is not very extended. It was adapted by Tooth to the purification of cane-juice at a central factory in Queensland, and is at present being successfully worked there in two instances. The mode in which it is carried out in the case of cane-juice is as follows:—

1. Crushing and Liming.—The canes are crushed the same day as they are cut, and the juice flows from the mills into tanks containing well-burnt caustic lime previously slaked with water to the consistency of a paste, and is constantly agitated to ensure thorough admixture with the lime;

when the tank is full, the proportion of lime is made up to 1–1½ per cent., and the whole is thoroughly mixed. These operations are carried on at the plantation, and the juice is then pumped through pipes, in some cases several miles in length, or conveyed in tank-barges, to the central factory; agitation being continued during the pumping, the pipes do not choke.

2. Reliming.—When the juice is received at the factory, a further proportion of slaked lime is added; if it is from good sound canes, about ¼ per cent. suffices, but if from unripe or damaged canes, a larger quantity of lime is used. The store-tanks in which the juice is received are mostly made of concrete or of iron; they are of large capacity (30,000–50,000 gal.), and fitted with agitators worked by machinery, which keep the lime constantly suspended. If properly agitated, the relimed juice can be kept for several weeks without undergoing any decomposition. It is now ready for gasing.

3. Gasing.—A kiln is constructed for obtaining carbonic acid from the calcination of limestone; the lime is afterwards used for liming the juice, and the carbonic acid gas is drawn off by pumps or exhausters. The kiln is constructed to burn continuously, the limestone being fed in from the top. The products of combustion are drawn away through a 16-in. wrought-iron pipe, and cooled and washed by passing through a couple of scrubbers, so that the temperature of the gas when used is not more than 18°–24° (65°–75° F.). The lime taken from the kiln is carefully hand-picked, and, for the preparation of the sucrate, only those lumps are slaked which are properly burnt, and free from the mineral matters introduced by the fuel used in the kiln. The limed juice in quantities of 1000–1500 gal. is pumped into tanks, called *émousseurs*, of 5000–7000 gal. capacity, provided with revolving stirrers consisting of a hollow vertical shaft fitted with hollow arms, arranged to revolve in a horizontal position within a short distance of the bottom. The hollow shaft is connected with the exhausters by which the carbonic acid gas is being drawn from the kiln; and the hollow arms are perforated with a series of holes, so as to allow the gas to escape within a few inches of the bottom of the *émousseurs*. This hollow agitator is kept in rotation by machinery, and the tanks are ⅕ filled with relimed juice, which must be cool.

Carbonic acid gas is then forced under pressure in a rapid stream through the juice. At first, the liquid froths excessively, the froth frequently rising nearly to the top of the tank; to modify this, the vertical shaft is fitted with rakes, which revolve with it and break the froth. The appearance of the juice is carefully observed, and a point is at length reached when the froth commences to subside. This is the indication of the approach of the completion of the first gasing, and the current of gas is then stopped, the agitation being continued, and a small sample of the juice drawn off for testing, as follows.

A sample is rapidly boiled and filtered while hot, the amount of clarification being noted by the appearance of the liquor, which should be then of a pale straw-colour.

The appearance of the partially decomposed precipitate of sucrate of hydrocarbonate of lime on the filter is examined. If too gelatinous, it indicates that stronger sucrate is present in the compound than necessary, and that more carbonic acid must be added in order to eliminate a larger proportion of the sugar. If, on the contrary, the precipitate is granular, the liquid of a dark sherry-colour, and all or nearly all the lime has been precipitated as carbonate of lime, too much gas has already been passed. The degree of alkalinity of the juice is also ascertained by titrating it with sulphuric acid, which affords a fairly effectual check on the amount of lime still left in solution. This quantity, if the process has been carried out successfully, is ·15–·2 per cent., varying within small limits, according to the richness of the saccharine juices, and the quantity of glucose which they contain. The point which it is desired to reach by this process is such that the quantity of sucrate of hydrocarbonate of lime in solution is sufficient to ensure that, during the subsequent processes, the impurities present in the juice shall be effectively carried down; but any excess over this quantity not only incurs loss of sugar, but increases the difficulty of filtration.

4. Boiling.—When the liquor is successfully gased to this extent, it is run down from the *émousseur* into a circular closed vessel heated by steam, in which it is rapidly boiled for a few minutes. This boiling precipitates certain compounds of lime and sugar, probably in the form of basic sucrates of lime mixed with carbonate of lime and with nearly the whole of the impurities contained in the juice. This precipitate contains also a small proportion of the undecomposed sucrate of hydrocarbonate of lime.

5. Filtering.—After boiling, the hot juice containing the precipitate and the precipitated impurities is run into a *monte-jus*, and forced by air or steam at a pressure of 40–50 lb. a sq. inch through filter-presses. These vary little from those in ordinary use, and commonly called "yeast presses." The mode of filtration is simply to force the precipitated liquor into a press until all the partitions, or "leaves," as they are technically called, as shown in Fig. 1313, p. 1848, are full of precipitate. This is known by the liquor ceasing to run from the taps of the presses. If the process has been properly carried out, the liquor will filter very rapidly, leaving the presses full of a good firm cake containing 9–12 per cent. of sugar, which can readily be removed by washing in the press (by a special arrangement) with boiling water and steam. In a juice-factory, it is found

better to reject this sugar than to incur the trouble and expense of recovering it, more especially as the wash-waters are weak in sugar, and contain some impurities dissolved from the cake; they therefore require considerable evaporation before the contained sugar becomes available. In practice, for every 100 lb. of lime added to the crude juice, there will be about 250 lb. of molaxa; as the proportion of lime used seldom exceeds 1½–2 per cent. on the juice, the loss of sugar incurred would be neglected in a cane-growing country, where the actual cost of the canes forms by far the smallest portion of the cost of the manufactured sugar. The filtered juice as it runs from the taps in the filter-press is perfectly bright and clear, of a light straw-colour, and slightly alkaline to test-paper. It is now submitted to a second gasing.

6. Second Gasing.—The clarified juice while still hot is pumped into tanks and regased, whereby a further quantity of lime is precipitated as carbonate of lime. The gasing is continued until the liquor is supersaturated with carbonic acid gas; the liquor is then boiled by steam-coils or otherwise, and run into subsiding-vessels, after which the supernatant liquid is filtered, generally through Taylor's bag-filters, and is ready for concentration, if sugar of low quality is required, or for treatment with animal charcoal. The produce of sugar obtained is better in quality and quantity if char is used, and one of the remarkable features of this process is that the quantity of char necessary is only ⅓–¼ of that which is required in the ordinary refining processes. After passing through the char, the juice is ready for concentration and crystallization. In some cases, it is considered desirable to re-treat the molasses, i. e. to carry them through the same routine again.

It will be apparent that the process is one of unusual complexity, and requires careful supervision, more careful, in fact, than most chemical processes. The advantages claimed for it are:—(1) Increased sugar-yield from a given quantity of juice, (2) improved quality of sugar, (3) reduction in size of charcoal plant, (4) decreased yield of molasses. On the other hand, it is evident that for a colonial sugar-house the following disadvantages will be found:—(1) The plant is expensive; (2) the labour required is of a high class, and skilled chemical supervision is essential in order to ensure correct and successful working; (3) when the juice is impure or from unripe canes, and contains much uncrystallizable sugar, a large proportion of glucate of calcium is formed, which, on account of its solubility, goes through all the stages of the process. The greater part of this glucate is thrown out in the molasses, but a small trace of it remains in the crystal sugar, and causes it to deliquesce and to have an offensive odour. When the proportion of glucate becomes high, it forms a sticky mass, which prevents a considerable proportion of the sugar from crystallizing out after the boiling of the syrups. It is stated that the best results hitherto obtained are:—From every gal. of sound juice at 10° B., nearly 1·5 lb. of pure crystallizable sugar have been extracted; but the molasses is so heavily charged with calcium salts as to be only fit for producing a very coarse spirit. It is especially necessary in this process to guard against the slightest tendency to fermentation, for when once ferment germs have been introduced, it is quite impossible to form the precipitate of hydrocarbonate of lime. When this is the case, the precipitate thus formed is of a slimy character, which clogs the filters so that no amount of pressure will force the liquor through the press.

Although such satisfactory results have in certain cases been obtained by this process, there is little doubt that it is too complicated for ordinary plantations, and must be much simplified before it will come into general use, except in large central factories capable of treating at least 30,000–50,000 gal. per diem.

For Refining Sugar.—Although the clarification is carried out in the same way, and similar chemical reactions take place in the precipitation of the impurities, yet the mode of conducting the process is necessarily somewhat different. It is essential to successful working that the raw sugar to be operated upon should contain only small proportions of uncrystallizable sugar, certainly not more than 6 per cent.; for this reason, beet-sugars are more easily refined than cane-sugars, and it is sometimes advisable to mix the two. Commercially, the standard quality of the raw sugar is kept up to a certain definite percentage of available sugar. This is done by analysing each parcel of sugar, and mixing so as to enable the refiner to work for one week or more on raw sugar of a constant composition. The standard of available sugar preferred is generally high, say 80–85 per cent., with a proportion of uncrystallizable sugar not exceeding 2–3 per cent. The method of working may be best described under the following heads:—(1) Melting the raw sugar, (2) preparing the sucrate, (3) application of the sucrate, (4) proportion added, (5) filtration, (6) regasing the filtered liquor. The raw sugar is melted in an ordinary blow-up, fitted with copper coils, so that closed steam is used instead of live steam, as in the ordinary method of refining. The sugar is melted with water to a density of 27–30° B. (cold). The thick sucrate is prepared by dissolving good beet- or cane-sugar, which should contain not less than 90 per cent. of available sugar, in cold water to 22° B. The quantity of crystallizable sugar in this solution is determined, and ⅕ of its weight of freshly-burnt caustic lime is slaked to a thick paste with water and added; the solution is kept cool and constantly stirred, and is pumped in quantities of say 1000 gal. to the *émousseurs*, and gased in a similar manner to cane- or beet-juice, except that in this case it is not necessary to have a revolving shaft, and the rakes can also be dispensed with, as the amount of frothing is less than in the case of low-density liquors: in fact some sugar-solutions do not froth at all. Fixed perforated pipes laid along the bottom of the tank supply the carbonic acid gas from the lime-kiln, and the gasing is continued until the liquor becomes thick and gelatinous from the formation of sucrate of hydrocarbonate of lime. The exact point at which nearly the whole of the crystallizable sugar is chemically combined with lime and carbonic acid is ascertained by the appearance of the substance, and its alkalinity to test-paper. It is important during this part of the process to keep the liquor as cool as possible, and the temperature should on no account be allowed to rise above 29½° (85° F.). The appearance of the sucrate is that of a cream-coloured gelatinous mass of the consistency of strong jelly; its chemical composition is—$3\,CaCO_3, C_{12}H_{22}O_{11}, 3\,CaO\,2\,H_2O$. It is discharged from the gasing-tank through a slide-valve into a gutter or pipe communicating directly with the blow-up, or into a reservoir placed underneath in such a position as to allow the sucrate to be readily run into the blow-up.

The reservoir into which the sucrate is discharged is made of a size to act as a measure of the quantity to be added to the raw liquor. Experimental tests are made with the sucrate to discover the right proportion to add to the raw sugar liquor, so as to obtain the best clarification with the greatest possible speed of filtration. It is sometimes necessary to determine the sp. gr. of the sucrate, and add the proportion by weight, as it not unfrequently happens that numerous bubbles of gas remain entangled in the gelatinous mass. The required proportion is added either to the liquor in the blow-up, or at the time of melting, running the sucrate in while the raw sugar is being melted. The proportion added varies greatly with the quality of the sugar and the strength of the sucrate formed, but it may be taken generally that 2000 gal. of liquor at 27° B. require 200–500 gal. of sucrate for clarification.

After mixing with the sucrate, the liquor is pumped into the heater and boiled rapidly, and then forced by steam or air-pressure from a *monte-jus* at a pressure of 50–60 lb. a sq. in. through the filter-presses. The filtered liquor, freed from impurities, and very slightly alkaline, is regased, boiled, and refiltered, and is then ready for passing through animal charcoal, which easily removes the small amount of colouring matter and impurities left.

On account of the large percentage of sugar which the molaxa or cake contains (25–30 per cent.), it is necessary to re-treat with water, either in a mortar-mill, in which case it is of course necessary to refilter, or better to wash the cake in the presses by means of steam and water, which can be readily done, so that the cake contains no more than 1–2 per cent. of sugar, the resulting sweet waters being used in the blow-ups for melting the sugar.

The advantages claimed for this process are—decreased cost of working, great saving of animal charcoal, and increased yield of sugar. From the success which it has attained in England and on the Continent, it is evident that, although somewhat complicated, it can successfully compete with the commoner systems. The great drawback is that with cane-sugars of low quality, much difficulty and uncertainty is experienced in working, partly on account of the large proportion of uncrystallizable sugar, also from the fact that the soluble salts of lime formed seriously retard the crystallization of the sugar. With beet-sugar, this objection does not hold good, and it is probable that this method or some modification of it will in the future supersede to a great extent the present processes.

Elution.—In the elution process (see pp. 1859–60), a sucrate ("saccharate" or "melassate") of lime is first formed, and then purified by the action of alcohol. For this purpose, Duncan and Newlands add to an aqueous concentrated solution of any compound of sugar with lime, a quantity of alcohol, and agitate the mixture for a short time, when the sucrates of lime are mostly precipitated, and can be separated by decantation or filtration. Good results are attained by an admixture of 1 vol. of the concentrated solution of sucrate with 2 vol. of alcohol. The deposited sucrates after separation may be washed with alcohol to further free them from saline and other impurities; sufficient water to dissolve the sucrates is then added, and the mass is heated in a still, to recover any adhering alcohol.

The purified sucrates may be decomposed by carbonation, or by the action of dilute sulphuric acid of sp. gr. 1·182, whereby the lime is precipitated, and the sugar is rendered available. The alcoholic solution remaining after the precipitation and separation of the sucrates is heated in a still until all the alcohol comes over.

They also purify by means of alcohol, the peculiar compound of sugar with lime and carbonic acid known as "sucro-carbonate of lime." This substance, prepared by Johnson's, Murdoch's, or other process, is washed with alcohol, to remove saline matters and other impurities. The purified sucro-carbonate is then heated with water in a still, to separate adhering alcohol, and is lastly decomposed by carbonation, or by the action of sulphuric acid of sp. gr. 1·182.

They further remove lime salts, produced by the action of lime upon saccharine solutions containing uncrystallizable sugar, by alcohol. The saccharine solutions are heated with sufficient lime to destroy any uncrystallizable sugar present (a quantity equal to the uncrystallizable sugar is sufficient), the syrup being afterwards preferably neutralized by carbonation; the syrup, now containing a quantity of lime salts, is concentrated, after which, alcohol is added, and a large part of the lime salts is precipitated. About 2 gal. of alcohol to 10 lb. of syrup gives good results. In this manner, syrup may be freed from uncrystallizable sugar without permanently increasing its saline constituents. The precipitated lime salts are separated by decantation or filtration. The alcohol contained in the syrup, and that adhering to the deposited lime salts, is recovered by distillation.

In the elution process as ordinarily conducted, the washing of the sucrate with alcohol occupies considerable time, and involves the use, even in a small factory, of a number of elutors of large dimensions. These inconveniences Newlands avoids in the following manner. In lieu of the ordinary atmospheric temperature for the elution of the sucrate, he employs alcohol at an elevated temperature, by which means the operation is performed in a very short time, and with the aid of small plant, whilst the results are equal, if not superior. With alcohol at 74°–77° (165°–170° F.), the washing may be performed in a few minutes. The alcohol may be heated by means of steam-jackets. After the washing, the purified sucrate is further treated in the usual manner.

The alcoholic solution containing the impurities is distilled to recover the alcohol, and the remaining residue, which contains a considerable quantity of sugar, is converted into sucrate of lime by any of the usual methods, and washed with alcohol at 74°–77° (165°–170° F.), by which means a large portion of the sugar is recovered.

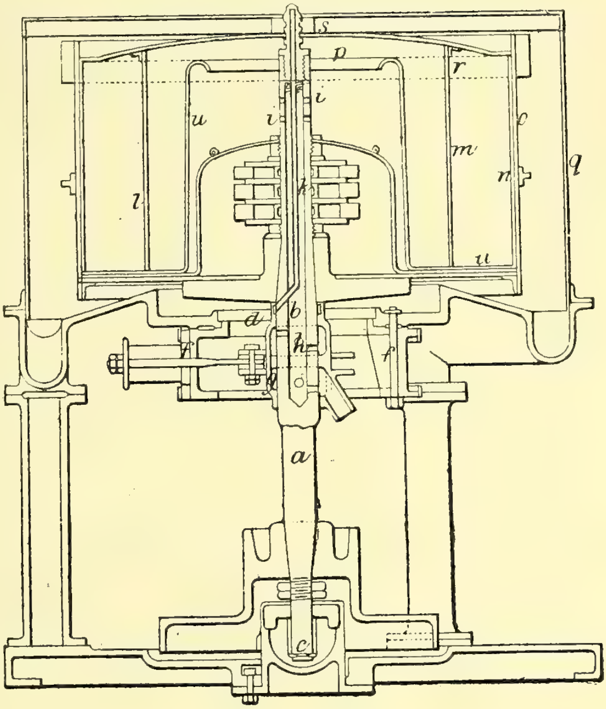
Centrifugals.—Ordinary centrifugals for curing raw sugar have been already described (see p. 1900).

Those used in refineries do not materially differ from those used in factories, except they are made of larger diameter, and therefore capable of holding a much larger quantity of *masse-cuite.* The time occupied in centrifugalling a charge of first crystal *masse-cuite* is 2–6 minutes, including washing or liquoring; the quantity of sugar turned out depends entirely upon the size of the machine, generally a turn-out of one or more cwt. of refined sugar constitutes a fair charge. The *masse-cuite* should be fed into the centrifugal a few moments after the latter has been started, but before it has attained its full speed. The syrup from centrifugals, if sufficiently pure and free from colour, is diluted to 30° B., and boiled for second crystals. These are smaller, and obtain a sale as such; occasionally, however, a special mechanical appliance is attached to the vacuum-pan, by means of which a quantity of these crystals can be drawn in during the boiling of the liquor, and after the pan has started (but before grain has been obtained), without destroying the vacuum. These crystals are fed in the usual way, and any slight colour or blemish which they may have had is coated over with the sugar deposited in increasing their size. After two boilings, the syrup again becomes discolored, and contains the whole of the mineral and organic impurities. These syrups are reboiled to a "jelly," run into coolers, and, after standing one or two days to crystallize, are centrifugalled in machines capable of holding 10–20 cwt. The sugar obtained, which of course has considerably decreased in yield, is of a light-yellowish colour, soft, and having little or no grain, and is known under the name of "refiners' pieces." The yield depends entirely upon the quantity of available sugar which the *masse-cuite* contains, but generally amounts to 20–40 per cent. of the weight of the *masse-cuite.* The final syrup is boiled, and allowed to stand in coolers for some weeks, in order to obtain the whole of the sugar capable of crystallizing. It is machined, and forms a lower quality of "pieces," or, if too bad for this, is sent to the blow-up to be again passed through the refining operations. Generally it requires three or four crystallizations before the whole of the sugar is obtained. The residual syrup or molasses is highly charged with impurities, and is either sold as such, or partially purified, and inverted by treatment with acid, as described on pp. 1915–6, and sold as brewing sugar.

Duncan and Newlands dispense with the direct action of steam, as sometimes employed, and subject the sugar contained in the centrifugal to the action of a spray produced by causing steam or air to act upon water, saccharine solutions, or alcohol, in such a manner as to diffuse them in a fine state of division; and construct the centrifugal with a hollow spindle for this purpose. Fig. 1410 shows a vertical section of the machine. *a* is the hollow spindle, with a passage *b* for the introduction of the spray, turning in a footstep-bearing *c*, and working in a bearing *d*, carried by a projecting bar *e*, secured to the frame *f* in such a manner as to admit of the requisite freedom of movement of the machine, whilst retaining the bearing *d* firmly in position. This bearing is recessed on its interior, so as to form an annular duct *g* for the admission of the spray, which is thence conducted into the passage *b*, through apertures *h*, and is discharged into the sugar through other perforations *i*, formed in the sides of the spindle, or in the top. The central pipe *k* is provided for lubricating the bearing *d*. The removable casing, constituting a core around which the sugar is introduced, is constructed with sides of the cores *l* perforated; and the core is retained in the machine after charging, the spray passing through the sides of the core into the charge in the annular space *m* between the exterior of the core *l* and the interior of the lining *n* of the drum or cage *o*. The lid *p*, attached to the drum *o* instead of to the outer casing *q*, entirely covers the drum *o*, and is provided with an annular rim *r* to encircle the upper end of the core *l*, the lid *p* with the core *l* being together retained in position by a nut *s* screwed into the threaded upper extremity of the spindle *a*.

Sugars cleansed in centrifugal machines by steam admitted to the inside of the drum are apt to have a grey appearance. Boegel and Gill found this to result from particles of dust lodging between and on the crystals of sugar, this dust being carried in by the air which is drawn through the centrifugal. To remedy this defect, the casing by which the revolving drum of the centrifugal is surrounded, is covered at top by a lid, whose under side carries a hollow casing, called the "distributor," which enters and occupies the greater part of the central space of the revolving drum. Means are provided for forcing into the interior of this distributor either moist or dry, warm, clean air. The air escapes into the lower part of the drum, and is thrown against the wall of sugar. When a charge of sugar has been filled in, the lid is lowered, the drum is revolved, and warm, moist, clean air is forced into the lower part of the drum. When the sugar has arrived at a clean crystalline state, the warm moist air is replaced by warm dry air, and the sugar is thus quickly dried. The movement of the drum is then arrested, the cover is lifted, and the sugar is cut out.

1410.



Many other processes have been from time to time employed for the purpose of dispensing with the use of charcoal. Weinrich's machine, which consists of a covered centrifugal described on p. 1934, Fig. 1410, is in use for freeing beet-crystals from some of their objectionable salts; it has been applied also to cane-sugars, and answers fairly well when the sugars are grainy in character; but for soft raw sugars containing much molasses, the time occupied in purifying the sugar, and the great loss of weight caused by the steam melting the fine grains of sugar, render it of little value except under peculiar circumstances. The yield with raw non-grainy sugars is 50–60 per cent., and the time occupied in purging a charge of 300 lb. sugar is 40–50 minutes. Raw sugar containing about 80 per cent. of crystallizable and 6 per cent. uncrystallizable would yield about 50 per cent. of sugar in hard blocks, of a dirty grey appearance, polarizing say 96 per cent., but containing a considerable proportion of the mineral impurities, with probably not more than 1 per cent. of uncrystallizable; the remainder of the crystallizable sugar has been melted by the action of the steam, and carried into the molasses. This process is at work in the refinery of James Duncan, for purifying beet-sugars, and at the Oriental Refinery, Hong-kong.

Where raw sugars are prepared by melting and graining in the vacuum-pan, and passed through this machine previous to being refined by charcoal in the manner already described, it is necessary to first grain in the vacuum-pan, otherwise the objections to the process when used for soft sugars, already urged, hold good. Of course, the larger the crystals, the less time does it take to purify, and consequently the greater the yield. Refining by successive crystallizations is of little or no value. It is carried out by melting the sugar, boiling for grain, centrifugalling, and reboiling the successive syrups. Only three crystallizations can be obtained by this plan, and the third is almost as bad if not worse in colour than the original sugar. About 50 per cent. of the total sugar is obtained from the first *masse-cuite*, 16–20 from the second, and 8–12 from the third, the molasses being fit for nothing except distilling.

Summary of Patents.—A short summary of the various patents which have been taken out for the manufacture of sugar, and for the various processes connected therewith, affords a convenient mode of tracing the progress of inventions in this industry, and of indicating what processes and methods tried by previous inventors have not proved commercially satisfactory, or have failed to secure acceptance by practical manufacturers and refiners. These notes will include some processes which, even after the patents have lapsed, have come into use, but they will not include second or third repetitions of a patent.

Since the commencement of the patent law, nearly 900 patents have been taken out for different processes, apparatus, and methods in connection with the manufacture or refining of sugar. These will be divided into classes, eliminating all such as show no clear novelty, or indicate nothing upon which a fresh invention can be readily based. A large number of processes which seemed to promise good results have failed when brought into actual work; and although sometimes a following inventor has improved a little on the original, it is impossible in every case to enter into the details essential to show in what points the subsequent improvement differed from it. Several of the most successful processes in use at present in sugar-refining do not appear at all in the records of the Patent Office, and some of the lapsed patents contain the elements of what have subsequently proved valuable processes. The summary will therefore consist of short notices only of patents in which novel ideas are put forward.

1. *Treatment of the Sugar-cane.*—The current systems of extracting cane-juice are described on pp. 1873–83. The methods which have been proposed for the purpose of more fully extracting the juice are:—

1848, No. 12033, Newton: cutting the sugar-cane into small pieces, afterwards dried in a kiln, and pulverized so as to facilitate the extraction of the sugar from the powder. This cutting and pulverizing has been repatented on various occasions since.

1853, No. 1243, Manfold and others: reducing canes to "saw-dust" by means of circular saws, and then pressing the juice out with the aid of live steam to dissolve the soluble matters. This also has been repeatedly patented since, but the mechanical power required has proved too great.

1876, No. 3539, Murdoch: cutting the canes into thin slices at an angle of about 45° to the length of the cane, grinding them between rollers of peculiar construction (the surface being cut with helical or screw threads in reverse directions, in order that the thin slices might be disintegrated), and afterwards subjecting the pulp thus obtained to pressure for extracting the juice.

None of these peculiar processes seem to have come into practical use.

2. *Evaporating Apparatus* (see pp. 1854–7).—A large number of patents have been taken out for evaporating sugar-liquors by supposed economical methods:—

1871, No. 4130, Wyatt: rotating discs, cylinders, or tubes, the lower part of which dip during the rotation into the vessel which contains the boiling juice or liquor, while the upper part is exposed to the air. This idea has been patented many times with slight modifications; the main difficulty in connection with its use is that the sugar dries on to the discs during the rotation in the form of a concrete or almost gelatinous mass, containing a large proportion of inverted sugar.

1845, No. 10474, Gadesden: an apparatus almost identical with Wyatt's.

1862, No. 1242, Fletcher: another similar one.

1865, No. 418, Fryer: the first step towards what is now known as "Fryer's Concretor" (see pp. 1898–1900).

1867, No. 3721, Tooth: a scrubber similar to that ordinarily used for gas-works. Obviously this would only be applicable to dilute solutions; if concentrated solutions were used, the packing of the scrubber would become coated with the sugar, and the sugar would be destroyed or inverted.

1868, No. 796, Tooth: the application of an exhaust to this scrubber, with arrangements for heating the lower part, to facilitate the evaporation.

1870, No. 1900, Johnson: a series of vacuum-pans placed on ascending levels so that the vapour rising from the lowest might be used as the heating agent for the one next above, the series comprising a multiple-effect (see pp. 1895–8).

1877, No. 3477, Fryer: improvements on his concretor, which have come into practical use to a considerable extent (see pp. 1898–1900).

Vacuum-pans.—The more modern forms of these are described on pp. 1893–8. As at present worked, they are used for almost all classes of raw and refined sugars.

The inventions to be referred to now mainly relate to the earlier stages, but it does not appear from the patent records that any one specifically patented the vacuum-pan itself or claimed its use as a distinct invention. All that is evident is that step by step improvements have been made in the mode of using it, or in the appliances connected with it, without anything to indicate to whom the invention originally belonged, as far as its application to sugar is concerned.

1867, No. 2213, Gordon: a discharge-chamber fixed to the bottom of a vacuum-pan in the form of a pocket, with the object of allowing the removal from time to time of the heavier crystallized portions of the sugar settled at the bottom, without the admission of atmospheric air and consequent destruction of the vacuum.

1871, No. 1777, Brough & Fletcher: alterations in the air-pumps and injection-nozzle, the object being to allow the injection-jet to spread as a solid sheet of water instead of as a spray; also electro-plating the interior of the vacuum-pan, to prevent the action of the sugar-liquors upon the metal of which it was composed.

1871, No. 3232, Robertson: exhausting the pan by means of steam-jets instead of an air-pump, using the jet on the principle of the now well-known Giffard or Körting injector.

1872, No. 287, Chapman: constructing a triple-effect in which the vapour from the first pan passes into the tubes of the second, and that from the second into the tubes of the third, the three pans being placed vertically on ascending levels, and differing very little, except in the number of the pans, from Johnson's. As regards real improvements in double- and triple-effects, and in the construction of the pans, so as to get better results from the same amount of steam, there is hardly anything in the patent records worth noting, except Rillieux's (see p. 1897).

3. *Filtration.*—Considering the great importance of this process in connection with the manufacture and treatment of sugar, the Patent Office records contain singularly little information of value.

1824, No. 4949, Cleland: bag-filters 6 ft. long and 3–4 in. diameter, which practically formed the first step towards the well-known Taylor-filter now universal in sugar-refineries.

1854, No. 792, Nash: accelerating filtration of sugar-liquors and liquoring of loaves by producing a vacuum below the sugar to be filtered or liquored, or by increasing the atmospheric pressure on the top.

1856, No. 1083, Finzell and others: the use of Needham & Kite's presses, better known in their modern forms as "yeast-presses," working under pressure, for facilitating the filtration of sugar-liquors.

1863, No. 2282, Cowen: the use of a vacuum for assisting filtration of the liquor through charcoal.

Charcoal and Substitutes for it.—These form a branch of filtration.

1860, No. 212, Duncan and others: the use of internal tubes inside the retorts in which the animal charcoal is reburnt, for the purpose of allowing the gaseous products of combustion to escape more readily, and effect considerable improvements in the quality of the reburnt charcoal.

1860, No. 2104, Belton: an artificial substitute for charcoal, made by calcining a mixture of bog-peat and chalk.

1861, No. 3275, Le Plat: revivifying animal charcoal by a wet process, consisting in washing with boiling water and milk of lime, and treating with live steam until the disengagement of ammoniacal vapours entirely ceases; also the addition of bibasic phosphate of lime or phosphate of magnesia to the revivified charcoal. In some cases, he uses acid to wash out any excess of carbonate of lime, and in some cases carbonate of soda or caustic soda to remove any organic acids which might remain.

1865, No. 1409, Muller and others: a substitute for charcoal, consisting of a mixture of China-clay, whiting and charcoal, saturated with a solution of ulmate of ammonia, and carbonized.

1864, No. 2409, Gaade: an artificial refining powder made from powdered animal charcoal mixed with argillaceous earth into a pasty mass, dried and calcined before use.

1865, No. 3078, Gaade: the use of soot, carbonized blood, and carbonized flesh, mixed with clay or other suitable plastic material, and then dried and calcined.

1866, No. 258, Montclar: another mixture of soot, with vegetable or animal charcoal, coke, gas-carbon, carbonized animal matters, and other carbonized matters, all being powdered, mixed with urine or solutions of gelatine, and dried and calcined.

1866, No. 1640, Patrick: a process of revivifying spent charcoal by allowing it to ferment, and then passing carbonate of soda through it prior to washing.

1870, No. 309, Eipfeldt and another: treating the charcoal after fermentation and steaming with caustic ammonia until thoroughly cleansed.

1876, No, 2535, Lugo: treating spent charcoal with solution of boric acid, in the proportion of $\frac{1}{16}$–1 part by weight of the acid, to 100 parts of the bone-black, and afterwards calcining it.

4. *Centrifugal Machines.*—The patents under this head are not of much importance, and as descriptions of the better classes of machines are given on pp. 1900, 1934–5, few will be referred to here.

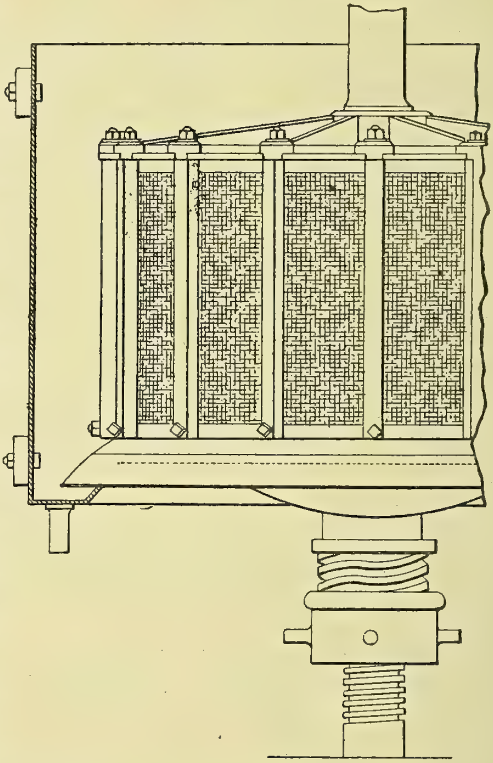
1843, No. 9898, Hardman: apparently the first patent for the use of a centrifugal machine; from Fig. 1411 it will be seen that though the idea was somewhat crude, it was a remarkably good first step towards the process now almost universally employed for draining the mother-liquor from the sugar.

1847, No. 11920, Playfair & Hull: arrangements for continuous feeding of the *masse-cuite* into the machine while it is running.

1860, No. 1981, Fryer: keeping the atmosphere inside the casing of the machine in which the drum rotates warm and damp by means of a jet of steam.

1867, No. 1178, Merrill: an arrangement for removing the charge of sugar from the machine without stopping the rotation of the cage, effected by an internal receiver furnished with a series of scrapers hanging upon pivots, so that when these scrapers are simultaneously opened by a handle or lever, the dried sugar is removed from the cage and brought into the internal receiver, which is afterwards lifted from the machine while it is running.

1411.



1869, No. 235, Lafferty & Lafferty: improvements in the mechanical details of the machines so as to provide for more effective lubrication, and to diminish the vibration in case the cage is unequally loaded; also driving the machine by cone- or friction-gearing instead of spur-gear.

1870, No. 679, Wigner: a scoop, actuated by a slide-rest for removing the sugar while the cage is running.

1870, No. 2886, Lesware: a machine in which the basket is made removable from the spindle, so that as soon as the charge is dried, the cage may be lifted off and replaced by another containing a fresh charge.

1871, No. 3222, Lafferty & Lafferty: improvements in the friction-gear for starting and stopping the machine.

1874, No. 755, the same: further improvements, as shown in Fig. 1412, the most important having reference to providing an easy mode for discharging the dried sugar while the drum is rotating.

5. *Brewing-Sugars, Starch-Sugar, and Invert Sugar.*

1855, No. 565, Riley: manufacture of starch- or grape-sugar from starch by boiling flour or meal of any cereal with sulphuric acid under pressure, say 10 lb. a sq. in.

1859, No. 451, Garton: dissolving cane-sugar in water, and heating it to about 71° (160° F.) for 48 hours, agitating it during the first few hours, and then adding acid, which is neutralized by chalk at a later stage.

1859, No. 2138, Manbré: making brewers' sugar from a mixture of potato-starch and dextrine with rice- or maize-flour, and with diastase, malt, or sulphuric acid, and heating until the conversion into starch-sugar is complete; also defecating by lime, blood, animal charcoal, and other matters.

1864, No. 552, Manbré: use of strong iron vessels lined with lead, to serve as convertors, and raising the temperature of the starch during the process of conversion to 160° (320° F.), or say 90 lb. a sq. in., by which to avoid the formation of gummy matters and empyreumatic acrid oils; also the use of a much larger quantity of sulphuric acid, viz. 20 per cent., whereas 2–5 per cent. had been the maximum formerly used.

1867, No. 2760, Hallibone & Manbré: lining the high-pressure boilers used for conversion with lead, tin, copper, brass, silver, or platinum, by turning the edges of the sheets of metal between the flanges of the segments of which the boiler is composed, so that no portion of the iron is exposed to the action of the acid used in the process.

1869, No. 1897, Manbré: steeping barley, rice, maize, wheat, and other grains, nuts, roots, and other vegetable products in water, and masticating and grinding them for the purpose of separating the starch before submitting them to the converting process.

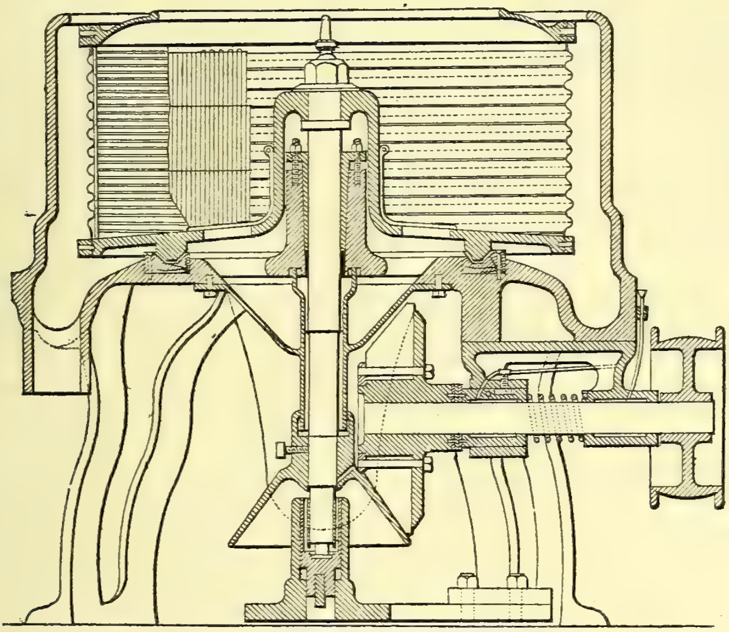
1870, No. 1562, Manbré: further improvements in the convertors, consisting mainly in the use of cast-lead linings, instead of the rolled lead previously employed.

1870, No. 205, Garton: adding to the solution in the convertor, animal char, or other substance containing phosphate of lime, so that when the excess of acids is neutralized, the precipitate of phosphates may defecate the sugary liquid.

1871, No. 1232, Garton: the preparation of brewing-sugars direct from raw cane-juice or beet-juice, by treating them with acid in the usual process of conversion, but without the juice having undergone the usual preliminary process of manufacture into sugar or syrup.

1874, No. 3639, Manbré: process and apparatus for converting starch into a mixture of dextrine and glucose, by agitating the starch with acidified water, and submitting it to dry heat over an open fire or in a stove, stirring continuously, so as to obtain a product in the form of a powder.

1412.



1875, No. 1724, Manbré: the addition of raw cane-sugar to the converted starch as it is run out from the convertor in the form of glucose, and subsequently heating the mixture in a vacuum-pan for ½ hour at a temperature not exceeding 149° (300° F.), at which temperature a chemical reaction is said to take place, producing a compound or new sugar, which is identical in sweetness and other properties with those sugars yielded by grapes and which produce the best brands of wine. After filtration, the mixed sugar can be again concentrated so as to form a solid sugar.

1874, No. 309, O'Sullivan & Valentin: the production of a compound solid body from starch or starchy substances, to which they applied the term "dextrine-maltose," and which is stated to consist of the same proportional quantities of dextrine and maltose as are ordinarily obtained from malt by the mashing process. The mode of operation is as follows:—The meal of rice or any other starchy substance, is introduced gradually, with constant stirring, into acidulated boiling water, containing 1½–3 per cent. of concentrated sulphuric acid in the proportion of 100 parts by weight of the meal to 250 parts of the acidulated boiling water, the mixture being made in an ordinary mash-tun. The transformation or conversion is arrested when the liquid contains in solution the requisite proportions of maltose and dextrine, ascertained by neutralizing the free acid, filtering, determining the sp. gr. of the filtrate, and estimating the proportion of oxide of copper reduced by the known weight or measure. The conversion is supposed to be complete when the quantity thus reduced indicates that about 44 per cent. of the glucose calculated on the total solid matter derived from the starch has been reduced. Another test given is that the transformation is complete if the specific rotatory power of the substance in solution for the transition tint is about 171°. The acid liquor is then neutralized with chalk or milk of lime until it is as nearly neutral as possible; to avoid excess of alkali, the liquor is evaporated in vacuum-pans until the compound body retains only 4–5 per cent. of moisture. It is directed that care be taken in packing the substance so as to prevent it from absorbing moisture.

1876, No. 2025, Valentin: the manufacture of "dextrine-maltose," and further improvements in the method of evaporation, consisting essentially in additional filtration, and in finishing the concentration in the open air instead of a vacuum-pan. By this change, it is claimed that the albuminoid substances which have not been removed by filtration are more completely oxidized, and that the finished article is consequently superior in quality.

6. *Various Chemical Substances.*—The number of chemical agents which have been patented for use, either in the treatment of cane- or beet-juice, or in refining and purifying sugar, is so great that space will not be occupied by always entering into the details of the manipulation proposed. In the absence of any statement to the contrary, it may be assumed, either that the experiments proved unsuccessful, or that the process was not brought to a practical trial.

1774, No. 1061, Fordyce: the use of blood for clarifying sugar.

1813, No. 3754, Howard: the use of alum, lime, and chalk (see p. 1887).

1815, No. 3912, Martineau and another: the use of animal charcoal, coke, certain kinds of ochres, and lamp-black.

1825, No. 5272, Jennings: washing raw sugar with rectified spirits of wine, or other alcoholic liquids, for the purpose of dissolving out the colouring matters and impurities.

1833, No. 6442, Terry & Parker: mixtures of sulphate of zinc, prussian blue, and lime, so proportioned as to produce what the inventors call "ferrocyanic acid." The sugar-liquor to be treated is boiled and "scummed" in the ordinary way, blood or white of eggs being used, and then the solutions containing the substances above mentioned are added while the liquor is boiling.

1838, No. 7573, Stolle: the use of alcohol charged with about 2 per cent. of sulphurous acid, subsequently washing the sugar with pure alcohol to remove the excess of sulphurous acid.

1847, No. 11790, Sievier: the use of the carbonaceous matter produced by the action of sulphuric acid on sugar as a means of purifying other sugar.

1847, No. 11991, Scoffern: acknowledging that salts of lead had previously been used for purifying sugar, claims the use of sulphurous acid for extracting the excess of lead which may have been left in the liquor; also a special mode of preparing the acetate of lead, which presents very little peculiarity (see p. 1888).

1849, No. 12617, Reece & Price: the use of hyposulphite of lime, in conjunction with acid sulphate of alumina, acetate of alumina, or similar substances; also the use of the combination of sugar and lime known as "saccharate of lime," to produce a magma of carbonate of lime and sugar, for the purpose of neutralizing the excess of acid which may have been used in any process.

1851, No. 13634, Oxland & Oxland: the use of phosphoric acid in a state of combination, for separating the residual lime or other chemicals which may have been left in the refined sugar.

1852, No. 14233, Egan: the expressed juice of the plantain for defecating raw sugar liquors or juice. The idea is doubtless taken from the custom which the natives of the Straits Settlements, China, &c., have of expressing the juice from the *Musa spp.*, diluting it with water, and using it to liquor the pots or *pilones* of raw sugar; the juice is rather acid, but it really purges the sugar very well, though it considerably reduces the weight by formation of molasses.

1852, No. 366, Nash: the use (1) of salts of tin for defecating the sugar—this has since been repatented upon several occasions; (2) of chlorine for removing or destroying the colour; (3) of ammonia for dissolving the albuminoid impurities from the sugar.

1853, No. 431, Hills: a filter of sawdust, phosphate of lime, or animal charcoal, to remove any residue of lead left in the sugar from the use of the subacetate of lead process for refining.

1853, No. 487, Brandeis: the use of salts of lead, tin, zinc, and bismuth, the only one which appears to be new being the bismuth; also removing the excess of these metallic salts through a filter of calcined shale or schist.

1853, No. 1510, Galloway: tannic, oxalic, gallic, or other acids, or combinations of these acids with potash or soda, for removing residual lead.

1853, No. 2358, Way: soluble silica to neutralize excess of lime.

1858, No. 655, Gilbee: washing the crude sugar with alcohol, and then treating it with sulphuric, tartaric, or other acids or salts.

1859, No. 58, Reynolds: the use of stannate of alumina.

1859, No. 370, Rousseau: the use of hydrated peroxides of manganese and iron.

1859, No. 1131, Reynolds: the use of meta-stannic, stannic, or tunstic acid, free or in combination.

1859, No. 1861, Possoz: the use of lime with subsequent carbonation at a somewhat high temperature, the resulting syrup being again treated with lime and recarbonated.

1861, No. 1956, Gemini: fullers' earth.

1861, No. 3112, Mennons: egg-albumen.

1862, No. 2294, Herepath: bleaching-powder.

1863, No. 2053, Dubrunfaut: the first application of the well-known phenomenon of osmosis for the separation of the organic and inorganic salts present in saccharine solutions from the sugar.

1866, No. 594, Gedge: cutting the cane or beet into small slices, and extracting the saccharine matters slowly by passing these slices successively through solutions containing less and less quantities of sugar, and finally into clean water, thus extracting the sugar by what is called the diffusion process (see pp. 1842–5, 1880–3).

1866, No. 2645, Beanes: the use of ozone.

1866, No. 3146, Jünemann: a gelatinous precipitate of saccharate of lime.

1867, No. 54, Johnson: treatment with lime and carbonic acid in a somewhat peculiar way.

1869, No. 1498, Robert: further modifications to adapt the diffusion process to the treatment of raw canes, so as to extract the saccharine matter by one continuous feeding process (pp. 1881–3).

1871, No. 1235, Duncan & Stenhouse: the use of sulphides and hydrosulphides of the alkaline earths for extracting iron from refined sugar.

1871, No. 1406, Dawlings: the use of carbonized iron ore.

1871, No. 1619 : Duncan & Stenhouse: the use of sulphuretted hydrogen and calcium sulphides and hydrosulphides, for removing metallic impurities.

1871, No. 2090, Duncan, Newlands, and Newlands: the use of sulphate of alumina to remove the potash salts present in the sugar or syrup, and the manufacture of alum thereby. This process is more fully described on pp. 1927–8.

1873, No. 3151, Tamin: the use of soluble silica and fluorides.

1874, No. 1736, Johnson: the use of alkaline carbonates prior to treatment of the sugar with alcohol.

1876, No. 240, Barrault: the "sucrate" process, which is more fully described on pp. 1930–3.

1877, No. 190, Bernard & Ehrmann: the use of magnesia.

1877, No. 583, Stuart: the use of hypochlorite of sulphur.

1878, No. 2211, Barrault: the re-treatment of the first crystal sugar by the sucrate process, in order to avoid the use of animal charcoal.

7. *Sundries.*—Under this heading are included a number of patents which are not readily classified with those previously referred to. Some two or three are noted mainly because of their peculiarities, and it is quite possible in one or two cases that useful ideas may be found in them.

1852, No. 797, Bessemer: "to prevent the drying of sugar, and to render it permanently moist, by the addition of saccharine or such other matters as do not readily evaporate on exposure to the air." This addition is to be effected by adding a solution of chloride of sodium, or such other saline matters as would render the sugar solution deliquescent, or uncrystallizable, and give the requisite moisture. In some cases, gelatine or glucose is proposed for the same purpose.

1862, No. 822, Fryer: the use (1) of very large crystallizing vessels not less than 30 ft. deep, and holding 50 tons of sugar, for crystallizing the sugar contained in the residual syrups; (2) after expressing the remaining syrups from the crystals, placing the *masse-cuite* in bags, and expressing the syrup by placing the bags one on another so as to form a column 20–50 ft. high. The first part has, with modifications of the size of the vessels, come into general use in many sugar-refineries; the second portion has, after repeated trials, been abandoned by the majority of refiners.

1864, No. 1342, Bertholomey: a process of feeding the growing crystals in the vacuum-pan by successive supplies or additions of concentrated syrup or clarified sugar. The patent hardly seems to have held its ground as a patent, but the process has come into considerable use, especially with those refiners who aim at the production of large crystals.

1868, No. 1845, Linard: the first step on the patent records towards the central factory system (see p. 1836). Although the invention as described here had not been patented before, very similar apparatus had been tried previously, substantially consisting in extracting the juice of the cane or beet on or close to the spot where they are grown, and supplying the juice as expressed to a central factory.

1871, No. 1185, Weinrich & Schröder: chilling the *masse-cuite* in moulds, and afterwards moving these moulds bodily into the centrifugal machine, so that the syrup is forced out, forming a kind of crude loaf; also liquoring this sugar in the machine, by means of "warm water in a state of mist," this warm water being obtained from a jet of steam let in with air into the interior of the revolving cylinder.

1874, No. 1870, Duncan (a communication from Weinrich): the addition of ultramarine or artificial ultramarine to the powdered, crushed, or crystallized sugar, in order to improve its quality and appearance; also certain modifications of centrifugal machines, so as to render them more suitable for this process, consisting essentially in the use of an inner cylinder, so arranged as to cause the sugar to form an even layer over the drum of the machine, which, being suspended in the drum by a swivel-joint, is capable of being removed shortly after the machine has been started, and while it is running.

1875, No. 4107, Duncan & Newlands: further improvements for the same purpose; also suggestions for the use of a spray of saccharine solution or alcohol in addition to water, for washing the sugar in the centrifugal (see p. 1934).

1875, No. 4420, Körting: another form of fog or damp air washing apparatus, for use in centrifugal machine.

1876, No. 2728, Gill: purifying the air which is conducted to the interior of the centrifugal machine by freeing it from dust (see p. 1935).

1876, No. 2685, Duncan & Newlands: further modifications of the centrifugal, to dry the steam supplied to the revolving cage.

1876, No. 2305, Schwartz: liquoring the dried sugar in the machine with water at 0° (32° F.).

1877, No. 3749, the same: a process for "imparting a bloom or complexion" to the sugar, by treating white or crystallized sugar with syrup or suitable solution of some uncrystallizable sugar.

Sugar Analysis.—The complete analysis of sugar, or of cane- or beet-juice, is in most cases a problem of considerable difficulty, because in all except the most pure white sugars, some organic matters are present, consisting of inverted sugar, colouring matters, waxy substances, and nitrogenous impurities, the accurate separation of which is all but impossible. For chemical purposes, it is customary, and one may almost say necessary, to put all these bodies together under a single heading as "organic matters not sugar." By this means, the analysis of sugar is brought within the compass of ordinary commercial work, and can be executed in a reasonable time.

It will be necessary to describe separately the analysis of cane-juice and beet-juice, but first the analysis of an ordinary raw cane-sugar or a refined sugar of moderate quality may be dealt with. The determinations usually made in such analyses are (1) cane-sugar, called crystallizable sugar, (2) uncrystallizable sugar, which includes invert sugar, (3) salts or ash, (4) moisture, (5) organic matters not sugar, generally reported as "unknown organic matters," (6) insoluble constituents, if any. Sufficient description will be given of what is included under the general term "uncrystallizable sugar"; but it is desirable to point out that the "salts" may be both organic and inorganic. The latter are by far the more important to the sugar-refiner, and consist chiefly of potash and lime salts, and smaller proportions of salts of soda, magnesia, and iron. These are frequently combined in the form of sulphates, phosphates, chlorides, carbonates, and silicates; but in raw beet-sugars, saccharates of lime and potash are very common.

Some 20 organic acids have been reported to be found in combination with the bases in sugar; but only an alphabetical list of them can here be given. They are,—acetic, aspartic, apoglucic, butyric, citric, formic, glucic, humic, lactic, malic, melassic, metapeptic, oxalic, pectic, succinic, tartaric, and ulmic. The organic matters in sugar contain certain alkaloids, especially betaine, peculiar to beet-sugar; certain nitrogenous matters, mainly albumen, legumine, and ferments; and certain non-nitrogenous organic matters, such as pectose, peptin, mannite, starch, colouring material, caramel, cellulose, gum, fat, and wax. The insoluble matters consist almost entirely of accidental mechanical impurities, such as sand and clay, with small proportions of the fibrous matter derived from raw sugar.

The process of analysis may now be described, with one preliminary remark. The difficulties which occur in the analysis of samples of sugar are due more to imperfect sampling than to error in analysis, owing to the fact that most low sugars contain such a very notable quantity of moisture that it is difficult to draw small samples such as may be used for the various processes with sufficient accuracy to represent the bulk. When the sample is a dark-coloured low sugar of the Jaggery class, it may contain as much as 10 per cent. of its weight of lumps of pottery and stones, and in many cases 7–10 per cent. of moisture. Great care must be taken to ensure thorough admixture before weighing the samples on which the analysis has to be made; it is also very essential to preserve the samples in well-closed bottles to prevent loss of moisture.

Characters of Cane-sugar.—Cane-sugar or sucrose is the variety of sugar which is extracted from the sugar-cane, a plant which grows only in tropical and subtropical climates, and which at one time supplied nearly the whole of the sugar consumed in Europe. It is extensively cultivated (see pp. 1860–71), and the manufactured product, under the name of "raw sugar," forms the staple produce of many of our colonies. Until recently, both the cultivation and manufacture (see pp. 1871–1902) of this most important article have been much neglected, and even at the present day some of the largest sugar-producing countries are exporting sugar, which, from its appearance and characteristics, has evidently been sadly spoiled during preparation. Sucrose is also extracted from the juice of the beetroot; it is identical in chemical composition with sugar extracted from the cane, and a considerable quantity is produced for consumption in Europe. More care is taken in the manufacture of sucrose from beet than from cane. Sucrose is likewise contained in the juices of many other plants, notably the sorghum and the palms; its manufacture is, however, virtually restricted to the sugar-cane, beetroot, sorghum and sugar-maple in America, and a small proportion from the wild date-palm in the East. Sucrose is found associated with invert sugar in the juice of many fruits: the following table by Payen shows the percentage proportions:—

	Cane-sugar.	Total Sugar.		Cane-sugar.	Total Sugar.
Pineapple (Montserrat)	11·33	13·30	Plum, Reine Claude	1·23	5·55
Strawberry (Collina d'Ehrherdt)	6·33	11·31	Orange	4·22	8·58
Apricot	6·04	8·78	Lemon	0·41	1·47
Apple, grey Reinette (fresh) ..	5·28	14·00	Raspberry	2·01	7·23
„ „ (preserved)	3·20	15·83	Peach	0·92	1·99
„ English	2·19	7·65	Pear, St. Germaine (preserved)	0·36	7·84
„ Calville (preserved) ..	0·43	6·25	Pear	0·68	8·78
Plum, Mirabelle	5·24	8·67			

Sucrose separates from a supersaturated solution in the form of monoclinic prisms, generally with hemihedral faces; its sp. gr. is 1·606; it is very soluble in warm water, but insoluble in ether and absolute alcohol; absolute alcohol when warm takes up a small proportion, which is again deposited on cooling. Heated to 160° (320° F.), it melts, and solidifies again on cooling, forming "barley-sugar." At higher temperatures than this, it suffers decomposition, losing water and becoming converted into a mixture of dextrose and lævulosan; and at still higher temperatures, it is converted into caramel. Its concentrated solution can be kept exposed to the atmosphere for some considerable time without suffering any sensible amount of deterioration; in weaker solutions, however, the sucrose is gradually transformed into invert sugar, more especially if the sugar be at all impure, in which case it is very prone to undergo fermentation.

Long-continued heating converts it into invert sugar, this change being more rapidly brought about in the presence of an acid; when treated with concentrated sulphuric acid, it is transformed (with evolution of sulphurous acid and other volatile products) into a black carbonaceous mass. With bases, it forms a class of salts known as sucrates; the alkaline earths combine with it, and its optical power is reduced, not however proportionally to the quantity of the base, but to the concentration of the sugar solution. Its specific rotatory power, which does not vary with the temperature, is 73°·8 for the transition tint. Various salts have the property of preventing sucrose from crystallizing.

Sodium chloride forms with it a compound having the formula $C_{12}H_{22}O_{11}$, $NaCl.2H_2O$. Concentrated sugar solutions dissolve a large proportion of lime, forming thereby compounds containing one, two, or three equivalents of lime, which are readily decomposed by carbonic acid gas. The calcium sucrates formed by treating concentrated solutions of sucrose with calcium hydrate are four in number. As several methods have been proposed for manufacturing or refining sugar by the aid of these compounds, they may be shortly described. The monobasic sucrate ($C_{12}H_{22}O_{11}CaO$), prepared by precipitating a saturated solution of sugar containing excess of lime with 85 per cent. alcohol, forms a white precipitate which, on drying, forms a brittle substance easily soluble in water. The bibasic sucrate ($C_{12}H_{22}O_{11}2CaO$) has been obtained by Boivin et Loiseau by several methods; it is easily prepared by precipitating with alcohol of 65 per cent. a saturated solution of sucrose with excess of lime, and boiling; it is decomposed by water into the tribasic salt and sugar. Sesquibasic sucrate ($2C_{12}H_{22}O_{11}3CaO$) is formed by boiling a solution of sugar with excess of lime; the compound separates out, and may be obtained as a white friable mass by evaporation in an atmosphere of carbonic acid. Tribasic sucrate ($C_{12}H_{22}O_{11}3CaO$) is precipitated in flocks resembling albumen, when a sugar solution containing excess of lime is heated; it is readily soluble in sugar water.

The formation of the peculiar sucro-carbonate of lime, the "sucrate of hydrocarbonate of lime" of Boivin et Loiseau, has been fully described under Sugar-refining (see pp. 1930–3). The chemical composition, which, however, varies with the density of the solutions, temperature, and proportions of sugar and lime, is $3CaCO_3$, $C_{12}H_{22}O_{11}.3CaO2H_2O$.

Sucrose is not directly fermentable, but first requires inverting. When its solution is mixed with yeast, it gradually becomes converted into invert sugar, and subsequently into alcohol and carbonic acid,—

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

Other compounds are also formed, as shown by Pasteur, e.g. glycerol (glycerine) and succinic acid, amounting to nearly 5 per cent., so that the proportion of alcohol produced is only 51–51½ per cent. instead of 54·97, the theoretical quantity. The action of the yeast is not thoroughly understood. Mineral acids greatly retard fermentation, which is also prevented by carbolic and sulphurous acids.

Determination of Crystallizable Sugar.—This is now universally made by means of the polarizing saccharometer, some forms of which are more fully described hereafter. All these polariscopes are graduated, so as to require a solution of sugar of some definite strength. With those which are most frequently used, viz. the Penombre and the Duboscq, the graduation is made for a 16·35 per cent. solution of sugar. The process will be described on the supposition of this being the required strength. Tables are given with the various instruments, and instructions as to the normal quantity of sugar to be taken.

The special apparatus required consists of weights weighing 16·35 *grm.* (the normal quantity), others for 13·175 *grm.* (the half-normal), and measured flasks having 2 marks on the neck, which is greatly elongated to allow of this. The lower mark represents 100 *cc.*, and the upper 110 *cc.* In addition to these, it is useful to have one or two flasks containing 150 *cc.* to the lower mark and 165 *cc.* to the upper. The balances should be capable of weighing this quantity within 0·01 *grm.*

To prepare a liquid for polarization, proceed as follows. Take a counterpoised basin provided with a lip well adapted for pouring, and weigh 16·35 *grm.* of the sample to be polarized. After weighing, pour about 50 *cc.* of water, preferably slightly warmed, on to the sample. As soon as the greater part of the sugar is dissolved, decant the solution into a 100-*cc.* flask, carefully dissolve out the remainder of the sugar, avoiding the addition of more water than is necessary, so as to keep the total volume of the solution below 80 *cc.* In the case of pure loaf and crystal sugars, this solution will be sufficiently clear and transparent to be capable of being polarized, and the solution may be at once made up to the full volume of 100 *cc.*; but the analysis of such samples is but rarely required, and in all other cases it is necessary to clarify the solution, in order to remove the colouring matter and render it sufficiently clear to be examined in the polariscope. This clarification is effected by the addition of an excess of a solution of basic acetate of lead, which causes an immediate precipitation of the colouring matters present in ordinary commercial sugars, and probably converts the glucose and invert sugar into salts of lead (glucate of lead), which have little or no action on polarized light. No precise rules can be given for the quantity of basic acetate of lead that is required; too large a proportion introduces error into the analysis, since it causes an increased volume of precipitate, and, according to some authorities, slightly increases the rotation of the sugar solution. With light-coloured refined sugars and pieces, 2 per cent. is generally sufficient; with darker muscovados, 3-5 per cent. is often required; and in the case of very low-grade sugars and molasses, the proportions may sometimes be as much as 7 per cent. The only guide is that enough must be added to completely precipitate the whole of the colouring matter, and the filtered liquor must be sufficiently bright and clear to enable the readings on the polariscope to be taken with ease.

After the addition of the basic acetate of lead, the flask is stoppered, thoroughly shaken and after standing until the froth has subsided, filled with cold water to the 100-*cc.* mark, and stoppered and shaken again sufficiently to mix the contents thoroughly. If the sugar is of low quality, it is generally better to add a small quantity of finely-powdered bone-black (say about ½ *grm.*), after which the liquid is again shaken. In dealing with sugars of medium colour, it is frequently a great improvement to remove the excess of acetate of lead by the use of sulphite of soda. The solution of this salt should be made of such a strength that vol. for vol. it is nearly or quite equivalent to the basic acetate of lead solution which is in use, and if say 5 *cc.* of basic acetate of lead solution have been used, 3 *cc.* of the sulphite of soda solution may be added after the flask has been shaken and before it has been filled up to the 100-*cc.* mark. This sulphite of soda effects the entire removal of the excess of lead, which is otherwise apt to become carbonated on exposure to the air, and so render the clarified solution turbid. Whichever method is adopted, the solution must now be allowed to settle, and filtered. The filter should rest in a suitable cylindrical vessel, so that the drops falling in the funnel shall be exposed but little to the air. A funnel 2½ in. diam. with a 4½-in. filter is the usual and convenient size.

The filtered solution is carefully transferred to one of the tubes of the polariscope; the long tube of 200 *mm.* length is that which is almost universally used, although for rather dark liquids a shorter one (100 *mm.* in length) is sometimes convenient. When properly filled and capped, the tube is transferred to the polariscope, and the rotation is read.

If the solution is too dark or coloured to polarize well, it is far better to weigh out a fresh quantity, and use an increased proportion of acetate of lead, rather than accept the indifferent or uncertain reading on the polariscope.

Determination of the Uncrystallizable Sugar.—This determination is less accurate than any other made in the ordinary course of sugar analysis, although with proper care the error should not amount to more than a fraction of a per cent. in ordinary cases, and 1 per cent. or thereabouts in the case of dark sugars and molasses. What is known as Fehling's solution is almost always adopted, although certain modifications have been introduced, which there will be occasion to refer to. This method depends upon the fact that an alkaline solution of sulphate of copper holding a salt of an organic acid (such as tartrate of potash), when added to a solution containing uncrystallizable sugar, and boiled, is decomposed, and a portion of copper present is precipitated in the form of cuprous oxide. The end of the reaction is ascertained, when the process is used as a volumetric one, by the disappearance of the blue colour of the solution of copper, or by the entire removal of the copper, as shown by testing a drop of the filtered liquid, previously acidified with acetic acid, with ferrocyanide of potassium. When the process is used as a gravimetric one, the precipitate is weighed as cupric oxide.

The Fehling solution is prepared as follows:—34·64 gr. of dry crystallized copper sulphate are dissolved in not more than 200 *cc.* of distilled water; in another vessel, 150 *grm* of neutral sodium potassium tartrate (Rochelle salt), to which is added 10 gr. of caustic soda (stick), are dissolved in about 100 *cc.* of water. The two solutions are mixed in a *litre* flask, diluted with water, and made up to 1 *litre* at 15° (59° F.); 10 *cc.* of this solution is equivalent to 0·05 *grm.* of invert sugar, and to different proportions of the other sugars by which it is reduced. This solution will not keep long, and on this account it is especially desirable that it should not be exposed to the light or air; but if the two solutions are kept separately, and mixed in the proper proportions shortly before use, they may be depended upon to remain unchanged for some months. Among the modifications which have been proposed is the use of ammonia, to which a small proportion of chloride of ammonium is added, and the quantity of caustic soda considerably increased; also that of Possoz, in which the quantity of sodium and potassium tartrate is greatly increased, and a large proportion of bicarbonate of soda is added; but it is doubtful whether either of these is any real improvement. In any case, it is especially desirable that pure crystallized sulphate of copper should be used, free from adhering moisture. It must not, however, be dried, except by pressing between sheets of filter-paper.

What is called the normal solution of sugar for the purpose of the uncrystallizable sugar determination, consists of 5 *grm.* of sugar made up to 100 *cc.* of solution in water. This strength answers well for most samples of raw and low refined sugars, as it will then correspond to about 0·5–0·2 per cent. of uncrystallizable sugar; but for sugars containing a large quantity of uncrystallizable sugar, the strength of the solution must be decreased, especially in the case of molasses; while for high-class crystallized sugars, it will sometimes be necessary to use a 20- or even 30-per cent. solution.

The volumetric test is carried out as follows:—A proportion of the before-mentioned solution of sugar is measured into a porcelain basin of 4 in. diam., supported on a retort-stand over an Argand burner, and diluted with about 100 *cc.* of water, and heated to boiling for a minute or two. A portion of the copper solution judged to be nearly sufficient to precipitate the uncrystallized sugar present is added from a graduated burette, and the solution is again boiled for one or two minutes. The lamp is withdrawn, and the liquid is allowed to settle. If it has attained a distinct blue tint, the proportion of Fehling solution added is too great, and it is necessary either to add a further proportion of the sugar to be tested, or to commence a fresh experiment. If, however, the solution is not blue, a few drops are removed by a pipette and transferred to a very small filter, the filtrate being collected in a suitable vessel. One drop of this filtrate is transferred to a porcelain slab or testing-tile, acidified with acetic acid, and a drop of a dilute solution of ferrocyanide of potassium is added. If a red colour is produced, sufficient copper solution has been added; if the colour is intense, or a precipitate forms, considerable excess has probably been used, and in that case the experiment should be repeated. If, however, no brown coloration is produced, more copper is required, and the few drops of filtrate are returned to the basin in which the boiling is taking place, and a further measured addition of copper solution is made. The whole is then boiled again, being previously diluted with water, if necessary, so as to prevent too much concentration; and the test with ferrocyanide of potassium is repeated in exactly the same way. These successive additions of copper are made and the tests are repeated until the drops of filtrate and ferrocyanide of potassium when mixed show a very faint coloration.

The first analysis is now complete, but as soon as the burette has been read off, it is desirable to repeat the analysis, as follows. Take another 50 *cc.* of the sugar solution, and run in from the burette a measured quantity of copper solution, to within 1–2 *cc.* of the total quantity used in the last experiment. Dilute, boil, and test the filtrate as before, and, if necessary, make successive additions of 1–2 *cc.* of copper solution, testing after each addition. The second test should be considered as the accurate one.

The gravimetric method depends upon the separation of the precipitated cuprous oxide. The process is carried out as follows. 100 *cc.* of the sugar solution are measured, and mixed with 25 *cc.* of the Fehling solution. The mixed solutions are heated on the water-bath for some minutes, and finally boiled. The solution must be examined to ensure that the copper solution is in excess, as indicated by the blue colour of the liquid. If this is not the case, a further measured quantity of the copper solution must be added. The precipitate is allowed to subside, the clear liquor is decanted through a filter, the precipitate is washed by decantation with hot water, the washings being passed through the filter, and finally the precipitate itself is washed with hot water on to the filter. The precipitate must be dried, the precipitated cuprous oxide carefully detached, the filter ignited in a spiral of platinum wire, the ashes added to the bulk of the precipitate, and the whole thoroughly ignited in a platinum crucible at a strong red heat. The residue must be moistened with a few drops of nitric acid, dried, and again ignited, and the cupric oxide weighed: 220·5 parts of cupric oxide correspond to 100 parts of anhydrous grape-sugar or dextrose. The washing of the filter free from alkali must be carefully attended to, as an error is very liable to be introduced from this cause, on account of the obstinacy with which the alkaline salts cling to the precipitated cuprous oxide, so that it is essential that the filter should be washed first by decantation, and then thoroughly with boiling water.

Brief reference must be made to one or two other methods occasionally used for the determination of uncrystallizable sugar, although not so often applied to the ordinary raw or refined sugars of commerce. In Gentele's method, when an alkaline solution of potassium ferricyanide is heated with invert sugar, it is reduced to ferrocyanide, and the yellow solution becomes decolorized. The standard solution is prepared by dissolving 109·2 *grm.* of potassium ferricyanide and 50 *grm.* of potassium hydrate in water and diluting to 1 *litre*; 10 *cc.* of this solution equals 0·010 *grm.* of invert sugar. 50 *cc.* of this standard solution are heated in a porcelain dish to a temperature of 75°–85° (167°–185° F.), the sugar solution being slowly added until the colour is discharged. The process is far more suitable for the brewing sugars commonly sold under the name of "glucose" than for ordinary raw sugars.

Determination of Water.—This is effected in the same way as the moisture of most vegetable products, by weighing a known quantity into a counterpoised watch-glass or capsule, and drying at a temperature of 101°–102° (214°–216° F.). With raw sugars of good quality, and especially large-grain refined sugars, there is no difficulty in the process, provided the temperature to which the sugar itself is actually exposed exceeds the boiling-point of water by 1° or 2°. The drying can be completed in 2–3 hours if a small quantity (1–1½ *grm.*) is taken. Some sugars, especially beet, absorb moisture so rapidly that it is essential that the cooling should take place under a desiccator, and that the drying should be repeated, and the dried sugar reweighed to see if any further loss takes place.

With low-grade sugars, such as Jaggery, and especially with molasses, the difficulty of drying is very great. It is essential in this case to reweigh 2 or 3 times. Sometimes when dealing with molasses containing a large amount of uncrystallizable sugar, and especially with molasses containing notable quantities of glucate of lime, it is necessary to add sand or powdered glass. The best method is to take a known weight of thoroughly washed and dried sand, and transfer it to a tared capsule, adding a small quantity (1–2 *grm.*) of the molasses to be examined, weighing again, then stirring the whole together with a piece of platinum wire of known weight, so as to produce an intimate admixture, and placing the capsule with all its contents, platinum wire included, in the air-bath. The temperature must be raised to at least 105° (221° F.), and the contents should be stirred with the platinum wire at intervals of ½ hour for some 3 hours, then moistened with alcohol, and redried. It will be necessary to weigh and redry once or twice, even after all these precautions; but when the loss between successive weighings falls as low as 0·2–0·3 per cent., it may be ignored, as the strong probability is that the decomposition of the sugar which is then taking place is producing a greater error than that which is caused by the comparatively small proportion of water which is not estimated. It is imperative to use a gas-regulator of some kind to regulate the heat of the air-bath. Borradaile's or Peeble's answer well for the purpose, or, if gas is not available for heating, a copper water-bath filled with the solution of chloride of calcium boiling at a temperature of 105° (221° F.) should be used instead.

Determination of Ash.—In this country and in France, it is the universal practice to return the ash as follows. It is ignited, moistened with sulphuric acid, again ignited, and weighed, and $\frac{1}{10}$ of the total weight thus found deducted. The reasons for this are two-fold: (1) the addition of the sulphuric acid facilitates the combustion of the sugar, and prevents the charred mass from becoming hard; (2) the bases present are all converted into sulphates, chlorine and carbonic acid being expelled, by which means the loss by volatilization and the error incurred by the expulsion of the carbonic acid gas at a red-heat are greatly diminished.

The ash should always be determined in a tared platinum dish of small size (2–4 *grm.* of the sugar sample are sufficient). The heat should be applied at first to one side of the platinum dish, and the flame gradually brought under the centre, so as to raise the whole to a moderate red-heat. The completion of the ignition is far more advantageously performed in a muffle, because the direct radiated heat from the top of the muffle burns off any carbon which may have assumed a graphitic character. When thoroughly ignited, the ash must be cooled under a desiccator, and weighed; the weight after deducting the tare of the dish is reduced by $\frac{1}{10}$, and calculated to per cent. on the sample. If this ash is excessive in quantity, it is frequently necessary to determine the insoluble ash as distinct from the soluble. This occurs most frequently with low sugars of the Yloilo and China class; in such cases, the insoluble impurities consist almost entirely of sand, alumina, and other such mechanical matters, and are of no more importance to the refiner than is represented by the proportion which they form of the sample. The soluble ash, on the other hand, represents those salts which pass into solution, and which hinder the crystallization of the sugar.

Sometimes it is necessary to determine the amount of alkaline salts, viz. carbonates of potassium and sodium present in the ash. This may be done accurately by executing a full mineral analysis of the sulphated ash, obtained as before described; but for commercial purposes, it is generally sufficient to adopt the following much more rapid process. The sugar is ignited without the addition of sulphuric acid, and calcined to a fairly grey ash. The residue in the platinum basin is boiled in water, and filtered. A few drops of carbonate of ammonia are added, the solution is evaporated to dryness and gently ignited at a low red-heat, and the contents of the basin are washed out into a flask and titrated with normal acid, calculating the results of the titration to potassium carbonate. As beet-sugar ash contains some 50 per cent. of potassium carbonate and 15–20 per cent. of sodium carbonate, the error incurred by this process is very small.

Unknown Organic Matter.—For ordinary commercial purposes, this is always determined by difference, i.e. by adding together crystallizable sugar, uncrystallizable sugar, ash, and moisture, and deducting the product from 100. It is obvious that this method affords no check upon the figures which have been obtained from the other processes, but it is practically essential in dealing with samples the analysis of which is required promptly, to use methods which are capable of rapid execution.

Results.—The results obtained by these analyses are always worked up in France, and practically in this country, to what is called the *rendement.* This figure is obtained in the case of beet-sugar by deducting the uncrystallizable sugar present, and 5 times the proportion of ash from the crystallizable sugar found. Thus supposing the crystallizable sugar was 90 per cent., the uncrystallizable sugar 1 per cent., and the ash 1 per cent., the *rendement* would be worked up by saying $90 - 1 = 89 - (1 \times 5) = 84$, and this would be, according to the view thus taken of it, the actual *rendement* or proportion of sugar which a refiner would be able to extract.

In the case of cane-sugar, only 3 times the ash is deducted, as, from the much smaller quantity of alkaline salts which these sugars contain, only about 3 times the weight of ash is rendered uncrystallizable instead of 5. It is often the case that with ordinary commercial sugars, the *rendement* thus obtained gives a very accurate estimate of the value of the sugar to the refiner, but there are certain cases in which the errors incurred are considerable.

Special Processes.—Having dealt with the ordinary and recognised commercial modes of sugar analysis, reference will now be made to those methods which are used as subsidiary processes in some cases of commercial work, and in other cases only for the purpose of special tests in refineries or sugar-*usines.*

Payen's process.—The alcohol process, which is often also called Payen's process, consists in washing the sample on a filter with alcohol of 88 per cent. strength, which has already been saturated with cane-sugar, and slightly acidified with acetic acid. The washing alcohol being already saturated with pure cane-sugar, cannot dissolve any more of that substance; but it is capable of dissolving uncrystallizable sugar and the salts occurring as impurities, while the acid which is present is sufficient in quantity to dissolve almost if not quite all the soluble matters not soluble in alcohol, and to decompose the sucrates. The test is carried out as follows. Three solutions are prepared, viz. (1) a mixture of absolute alcohol and ether, (2) 88 per cent. alcohol to which has been added 50 *cc.* of acetic acid per *litre,* and which has been saturated with pure crystallizable sugar (loaf-sugar answers perfectly well), (3) 95 per cent. alcohol also saturated in the same way with sugar.

The sample to be tested is weighed and transferred to a small tube, similar to a chloride of calcium tube, but preferably longer. Solution No. 1 is then passed on to the sugar in quantity equal to about the bulk of the sugar itself, so as not only to remove the water, but to precipitate any cane-sugar which may be in combination or solution in the water. If the raw sugar is too moist, it is desirable to dry it previously, so that it does not contain more than 4–5 per cent. of moisture. The chloride of calcium tube should be provided with a stopcock at the bottom, to allow the solvents to remain in contact with the sugar for a sufficient time.

After 10–15 minutes, the liquid may be run off by the stopcock at the bottom, and solution No. 2 added. The sample to be acted upon by this solution will be practically freed from water, and the diluted acetic acid solution will dissolve out any lime-salts which may be present, and so free the crystals of sugar from mineral impurities naturally existing in it. This solution is withdrawn in the same way as No. 1, and solution No. 3 is then poured on, a 2nd or 3rd portion of this solution being used if necessary until it ceases to take up anything more, and the sugar under treatment has reached its greatest whiteness of colour. After this, it is necessary to draw air through the tube containing the sugar, in order to remove the alcohol, and the residue of the sample is emptied from the tube into a tared capsule, dried and weighed, or if preferred, the crystals of sugar thus obtained may be dissolved in water made up to a definite volume, and polarized.

This process reads as a complicated one, and it is no doubt difficult of execution by those who are unused to it; but the opinion of some who have employed it is that the residue thus obtained (which is called crystallizable sugar) does really represent very closely the amount of crystallizable sugar which can be obtained by ordinary refining processes. The differences which occur in the execution of the analysis are mainly those due to alteration of temperature and possible changes in the strength of the solutions of sugar. A rapid fall in temperature in the laboratory during the process of washing will render the results incorrect, owing to the deposition of sugar on the surface of the crystals of the sample being washed.

Fermentation Process.—It has been proposed, and to some extent practically carried out, to determine the proportion of cane-sugar in the solution by means of the estimation of (1) the proportion of alcohol formed by fermentation, and (2) the amount of carbonic acid evolved during fermentation.

(1) A solution of cane-sugar when fermented yields 51–51·2 parts by weight of alcohol. The process is carried out by placing a dilute solution of the sugar to be tested, mixed with a small proportion of yeast (4–5 per cent.) in a flask, keeping it at a temperature of 22°–25° (71½°–77° F.) until the fermentation has ceased, which will be in 3–4 days. The solution is afterwards distilled, and the amount of alcohol is determined in the distillate in the usual way. The calculation from the proportion of alcohol found to cane-sugar is of course easy, although not always accurate, because secondary fermentation attended with the formation of lactic acid and other bodies may take place.

(2) The sugar solution is fermented in a similar way, but in a flask closed except through one outlet, by which the evolved gases are allowed to escape into a suitable absorption tube or tubes, the first of which is filled with chloride of calcium or sulphuric acid, so as to absorb the moisture, and the second with a weighed solution of caustic alkali, to absorb the carbonic acid. It will of course be necessary in this case to draw, by means of an aspirator or other suitable appliance, a considerable amount of air through the apparatus after the conclusion of the fermentation, in order to remove the last traces of carbonic acid. Uncrystallizable sugar will, according to this method of analysis, yield both alcohol and carbonic acid, and the carbonic acid is determined by the gain in weight of the caustic alkali due to absorption of carbonic acid.

Fehling's method.—It is well known that acids have the property of converting cane-sugar into invert sugar in definite proportion. It is thus possible to heat a solution of cane-sugar with a proportion of acid, and after the inversion of the sugar, to determine the total proportion of invert sugar present by means of Fehling's solution; but this method has proved very inaccurate in practice.

Inversion.—It not unfrequently happens that commercial samples of sugar contain substances which have an optical rotatory effect on the polariscope, and in this case it is necessary to employ the process of inversion. Cane-sugar is the only sugar which is capable of inversion by acids. Solutions of cane-sugar left in contact with air, especially when those solutions are diluted, do invert, and when acid is present they invert much more rapidly: the rate of inversion seems to be dependent partly on the time, partly on the strength, and partly on the amount of acid used, but for practical analytical work a definite process is carried out which results in the transformation of the whole of the cane-sugar into invert sugar in a very short time.

This process is as follows. 50–100 *cc.* of the clarified sugar solution is diluted with $\frac{1}{10}$ its volume of concentrated hydrochloric acid, and after admixture, the acidified solution is gradually heated to 68° (154° F.), the heating being so arranged as to occupy about 15–20 minutes. By this time, the cane-sugar present is wholly converted into invert sugar, and the solution is capable of being polarized, so that two readings of the polariscope before and after inversion may be compared.

If both readings are on either the right or left of the scale, the smaller is deducted from the greater, to give the angle of rotation sought; if, however, after inversion, the right-handed rotation is changed to left, so that the two readings are right and left of zero, their sums are taken, and the percentage of cane-sugar is found either by Clerget's tables, or by the following rule:—

A 16·35 per cent. solution of pure sugar, reading 100° to the right, will, when inverted, read 44° to the left, at 0° (32° F.); this action is expressed by

$$T = 144 - \tfrac{1}{2}T.$$

Therefore if S represents the sum or difference of rotations, T the temperature, and R the percentage of crystallizable sugar sought;

$$\text{then } 144 - \tfrac{1}{2}T : 100 :: S : R.$$

In this case, it is essential to note the temperature of the liquid when the second reading is taken, because invert sugar changes rapidly in its angle of polarization, according to its temperature.

This is not the case with cane-sugar.

The following are Clerget's tables referred to:—

Clerget's Table for the Analyses of Saccharine Substances.

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.)																										Per ct. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B. gram.
1·4	1·4	1·4	1·4	1·4	1·4	1·4	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1	1·64
2·8	2·8	2·8	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2	3·29
4·2	4·1	4·1	4·1	4·1	4·1	4·1	4·1	4·0	4·0	4·0	4·0	4·0	4·0	4·0	3·9	3·9	3·9	3·9	3·9	3·9	3·8	3·8	3·8	3·8	3·8	3	4·94
5·6	5·5	5·5	5·5	5·5	5·5	5·4	5·4	5·4	5·4	5·4	5·3	5·3	5·3	5·3	5·3	5·2	5·2	5·2	5·2	5·2	5·1	5·1	5·1	5·1	5·1	4	6·58
6·9	6·9	6·9	6·9	6·8	6·8	6·8	6·8	6·7	6·7	6·7	6·7	6·6	6·6	6·6	6·6	6·5	6·5	6·5	6·5	6·4	6·4	6·4	6·4	6·3	6·3	5	8·23
8·3	8·3	8·3	8·2	8·2	8·2	8·2	8·1	8·1	8·1	8·0	8·0	8·0	7·9	7·9	7·9	7·9	7·8	7·8	7·8	7·7	7·7	7·7	7·7	7·6	7·6	6	9·88
9·7	9·7	9·7	9·6	9·6	9·5	9·5	9·5	9·4	9·4	9·4	9·3	9·3	9·3	9·2	9·2	9·2	9·1	9·1	9·1	9·0	9·0	9·0	8·9	8·9	8·8	7	11·52
11·1	11·1	11·0	11·0	11·0	10·9	10·9	10·8	10·8	10·8	10·7	10·7	10·6	10·6	10·6	10·5	10·5	10·4	10·4	10·4	10·3	10·3	10·2	10·2	10·2	10·1	8	13·17
12·5	12·5	12·4	12·4	12·3	12·3	12·2	12·2	12·1	12·1	12·1	12·0	12·0	11·9	11·9	11·8	11·8	11·7	11·7	11·6	11·6	11·6	11·5	11·5	11·4	11·4	9	14·82
13·9	13·8	13·8	13·7	13·7	13·6	13·6	13·5	13·5	13·4	13·4	13·3	13·3	13·2	13·2	13·1	13·1	13·0	13·0	12·9	12·9	12·8	12·8	12·7	12·7	12·6	10	16·47
15·3	15·2	15·2	15·1	15·1	15·0	15·0	14·9	14·8	14·8	14·7	14·7	14·6	14·6	14·5	14·5	14·4	14·3	14·3	14·2	14·2	14·1	14·1	14·0	14·0	13·9	11	18·11
16·7	16·6	16·6	16·5	16·4	16·4	16·3	16·3	16·2	16·1	16·1	16·0	16·0	15·9	15·8	15·8	15·7	15·7	15·6	15·5	15·5	15·4	15·4	15·3	15·2	15·2	12	19·76
18·1	18·0	17·9	17·9	17·8	17·7	17·7	17·6	17·5	17·5	17·4	17·3	17·3	17·2	17·2	17·1	17·0	17·0	16·9	16·8	16·8	16·7	16·6	16·6	16·5	16·4	13	21·41
19·5	19·4	19·3	19·2	19·2	19·1	19·0	19·0	18·9	18·8	18·8	18·7	18·6	18·5	18·5	18·4	18·3	18·3	18·2	18·1	18·1	18·0	17·9	17·8	17·8	17·7	14	23·05
20·8	20·8	20·7	20·6	20·5	20·5	20·4	20·3	20·2	20·2	20·1	20·0	19·9	19·9	19·8	19·7	19·6	19·6	19·5	19·4	19·3	19·3	19·2	19·1	19·0	19·0	15	24·70
22·2	22·2	22·1	22·0	21·9	21·8	21·8	21·7	21·6	21·5	21·4	21·4	21·3	21·2	21·1	21·0	21·0	20·9	20·8	20·7	20·6	20·6	20·5	20·4	20·3	20·2	16	26·35
23·6	23·5	23·5	23·4	23·3	23·2	23·1	23·0	22·9	22·9	22·8	22·7	22·6	22·5	22·4	22·3	22·3	22·2	22·1	22·0	21·9	21·8	21·7	21·7	21·6	21·5	17	28·00
25·0	24·9	24·8	24·7	24·7	24·6	24·5	24·4	24·3	24·2	24·1	24·0	23·9	23·8	23·8	23·7	23·6	23·5	23·4	23·3	23·2	23·1	23·0	22·9	22·9	22·8	18	29·64
26·4	26·3	26·2	26·1	26·0	25·9	25·8	25·7	25·6	25·5	25·5	25·4	25·3	25·2	25·1	25·0	24·9	24·8	24·7	24·6	24·5	24·4	24·3	24·2	24·1	24·0	19	31·29
27·8	27·7	27·6	27·5	27·4	27·3	27·2	27·1	27·0	26·9	26·8	26·7	26·6	26·5	26·4	26·3	26·2	26·1	26·0	25·9	25·8	25·7	25·6	25·5	25·4	25·3	20	32·94
29·2	29·1	29·0	28·9	28·8	28·7	28·6	28·4	28·3	28·2	28·1	28·0	27·9	27·8	27·7	27·6	27·5	27·4	27·3	27·2	27·1	27·0	26·9	26·8	26·7	26·6	21	34·58
30·6	30·5	30·4	30·2	30·1	30·0	29·9	29·8	29·7	29·6	29·5	29·4	29·3	29·1	29·0	28·9	28·8	28·7	28·6	28·5	28·4	28·3	28·2	28·0	27·9	27·8	22	36·23
32·0	31·8	31·7	31·6	31·5	31·4	31·3	31·2	31·0	30·9	30·8	30·7	30·6	30·5	30·4	30·2	30·1	30·0	29·9	29·8	29·7	29·5	29·5	29·3	29·2	29·1	23	37·88
33·4	33·2	33·1	33·0	32·9	32·8	32·6	32·5	32·4	32·3	32·2	32·0	31·9	31·8	31·7	31·6	31·4	31·3	31·2	31·1	30·9	30·8	30·7	30·6	30·5	30·4	24	39·53
34·7	34·6	34·5	34·4	34·2	34·1	34·0	33·9	33·7	33·6	33·5	33·4	33·2	33·1	33·0	32·9	32·7	32·6	32·5	32·4	32·2	32·1	32·0	31·9	31·7	31·6	25	41·17
36·1	36·0	35·9	35·7	35·6	35·5	35·4	35·2	35·1	35·0	34·8	34·7	34·6	34·4	34·3	34·2	34·1	33·9	33·8	33·7	33·5	33·4	33·3	33·1	33·0	32·9	26	42·82
37·5	37·4	37·3	37·1	37·0	36·8	36·7	36·6	36·4	36·3	36·2	36·1	35·9	35·8	35·6	35·5	35·4	35·2	35·1	35·0	34·8	34·7	34·6	34·4	34·3	34·1	27	44·47
38·9	38·8	38·6	38·5	38·4	38·2	38·1	37·9	37·8	37·7	37·5	37·4	37·2	37·1	37·0	36·8	36·7	36·5	36·4	36·3	36·1	36·0	35·8	35·7	35·6	35·4	28	46·11
40·3	40·2	40·0	39·9	39·7	39·6	39·4	39·3	39·1	39·0	38·9	38·7	38·6	38·4	38·3	38·1	38·0	37·8	37·7	37·5	37·4	37·3	37·1	37·0	36·8	36·7	29	47·76
41·7	41·5	41·4	41·2	41·1	40·9	40·8	40·6	40·5	40·3	40·2	40·0	39·9	39·7	39·6	39·4	39·3	39·1	39·0	38·8	38·7	38·5	38·4	38·2	38·1	37·9	30	49·41
43·1	42·9	42·8	42·6	42·5	42·3	42·2	42·0	41·8	41·7	41·5	41·4	41·2	41·1	40·9	40·8	40·6	40·4	40·3	40·1	39·9	39·8	39·7	39·5	39·4	39·2	31	51·06
44·5	44·3	44·2	44·0	43·8	43·7	43·5	43·4	43·2	43·0	42·9	42·7	42·6	42·4	42·2	42·1	41·9	41·8	41·6	41·4	41·3	41·1	41·0	40·8	40·6	40·5	32	52·70
45·9	45·7	45·5	45·4	45·2	45·0	44·9	44·7	44·5	44·4	44·2	44·0	43·9	43·7	43·6	43·4	43·2	43·1	42·9	42·7	42·6	42·4	42·2	42·1	41·9	41·7	33	54·35

Clerget's Table for the Analyses of Saccharine Substances—*continued.*

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.)																										Per ct. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B.
																											gram.
47·3	47·1	46·9	46·7	46·6	46·4	46·2	46·1	45·9	45·7	45·6	45·4	45·2	45·0	44·9	44·7	44·5	44·4	44·2	44·0	43·9	43·7	43·5	43·3	43·2	43·0	34	56·00
48·6	48·5	48·3	48·1	47·9	47·8	47·6	47·4	47·2	47·1	46·9	46·7	46·5	46·4	46·2	46·0	45·8	45·7	45·5	45·3	45·1	45·0	44·8	44·6	44·4	44·3	35	57·64
50·0	49·9	49·7	49·5	49·3	49·1	49·0	48·8	48·6	48·4	48·2	48·1	47·9	47·7	47·5	47·3	47·2	47·0	46·8	46·6	46·4	46·3	46·1	45·9	45·7	45·5	36	59·29
51·4	51·2	51·1	50·9	50·7	50·5	50·3	50·1	49·9	49·8	49·6	49·4	49·2	49·0	48·8	48·6	48·5	48·3	48·1	47·9	47·7	47·5	47·4	47·2	47·0	46·8	37	60·94
52·8	52·6	52·4	52·2	52·1	51·9	51·7	51·5	51·3	51·1	50·9	50·7	50·5	50·3	50·2	50·0	49·8	49·6	49·4	49·2	49·0	48·8	48·7	48·4	48·3	48·1	38	62·58
54·2	54·0	53·8	53·6	53·4	53·2	53·0	52·8	52·6	52·4	52·3	52·1	51·9	51·7	51·5	51·3	51·1	50·9	50·7	50·5	50·3	50·1	49·9	49·7	49·5	49·3	39	64·23
55·6	55·4	55·2	55·0	54·8	54·6	54·4	54·2	54·0	53·8	53·6	53·4	53·2	53·0	52·8	52·6	52·4	52·2	52·0	51·8	51·6	51·4	51·2	51·0	50·8	50·6	40	65·88
57·0	56·8	56·6	56·4	56·2	56·0	55·8	55·5	55·3	55·1	54·9	54·7	54·5	54·3	54·1	53·9	53·7	53·5	53·3	53·1	52·9	52·7	52·5	52·3	52·1	51·9	41	67·53
58·4	58·2	58·0	57·7	57·5	57·3	57·1	56·9	56·7	56·5	56·3	56·1	55·9	55·6	55·4	55·2	55·0	54·8	54·6	54·4	54·2	54·0	53·8	53·5	53·3	53·1	42	69·17
59·8	59·5	59·3	59·1	58·9	58·7	58·5	58·3	58·0	57·8	57·6	57·4	57·2	57·0	56·8	56·5	56·3	56·1	55·9	55·7	55·5	55·2	55·0	54·8	54·6	54·4	43	70·82
61·2	60·9	60·7	60·5	60·3	60·1	59·8	59·6	59·4	59·2	59·0	58·7	58·5	58·3	58·1	57·9	57·6	57·4	57·2	57·0	56·8	56·5	56·3	56·1	55·9	55·7	44	72·47
62·5	62·3	62·1	61·9	61·6	61·4	61·2	61·0	60·7	60·5	60·3	60·1	59·8	59·6	59·4	59·2	58·9	58·7	58·5	58·3	58·0	57·8	57·6	57·4	57·1	56·9	45	74·11
63·9	63·7	63·5	63·2	63·0	62·8	62·6	62·3	62·1	61·9	61·6	61·4	61·2	60·9	60·7	60·5	60·3	60·0	59·8	59·6	59·3	59·1	58·9	58·6	58·4	58·2	46	75·76
65·3	65·1	64·9	64·6	64·4	64·1	63·9	63·7	63·4	63·2	63·0	62·7	62·5	62·3	62·0	61·8	61·6	61·3	61·1	60·9	60·6	60·4	60·2	59·9	59·7	59·4	47	77·41
66·7	66·5	66·2	66·0	65·8	65·5	65·3	65·0	64·8	64·6	64·3	64·1	63·8	63·6	63·4	63·1	62·9	62·6	62·4	62·2	61·9	61·7	61·4	61·2	61·0	60·7	48	79·06
68·1	67·9	67·6	67·4	67·1	66·9	66·6	66·4	66·1	65·9	65·7	65·4	65·2	64·9	64·7	64·4	64·2	63·9	63·7	63·4	63·2	63·0	62·7	62·5	62·2	62·0	49	80·70
69·5	69·2	69·0	68·7	68·5	68·2	68·0	67·7	67·5	67·2	67·0	66·7	66·5	66·2	66·0	65·7	65·5	65·2	65·0	64·7	64·5	64·2	64·0	63·7	63·5	63·2	50	82·35
70·9	70·6	70·4	70·1	69·9	69·6	69·4	69·1	68·8	68·6	68·3	68·1	67·8	67·6	67·3	67·1	66·8	66·5	66·3	66·0	65·8	65·5	65·3	65·0	64·8	64·5	51	84·00
72·3	72·0	71·8	71·5	71·2	71·0	70·7	70·5	70·2	69·9	69·7	69·4	69·2	68·9	68·6	68·4	68·1	67·9	67·6	67·3	67·1	66·8	66·6	66·3	66·0	65·8	52	85·64
73·7	73·4	73·1	72·9	72·6	72·3	72·1	71·8	71·5	71·3	71·0	70·7	70·5	70·2	70·0	69·7	69·4	69·2	68·9	68·6	68·4	68·1	67·8	67·6	67·3	67·0	53	87·29
75·1	74·8	74·5	74·2	74·0	73·7	73·4	73·2	72·9	72·6	72·4	72·1	71·8	71·5	71·3	71·0	70·7	70·5	70·2	69·9	69·7	69·4	69·1	68·8	68·6	68·3	54	88·94
76·4	76·2	75·9	75·6	75·3	75·1	74·8	74·5	74·2	74·0	73·7	73·4	73·1	72·9	72·6	72·3	72·0	71·8	71·5	71·2	70·9	70·7	70·4	70·1	69·8	69·6	55	90·59
77·8	77·6	77·3	77·0	76·7	76·4	76·2	75·9	75·6	75·3	75·0	74·8	74·5	74·2	73·9	73·6	73·4	73·1	72·8	72·5	72·2	72·0	71·7	71·4	71·1	70·8	56	92·23
79·2	79·0	78·7	78·4	78·1	77·8	77·5	77·2	76·9	76·7	76·4	76·1	75·8	75·5	75·2	74·9	74·7	74·4	74·1	73·8	73·5	73·2	73·0	72·7	72·4	72·1	57	93·88
80·6	80·3	80·0	79·7	79·5	79·2	78·9	78·6	78·3	78·0	77·7	77·4	77·1	76·8	76·6	76·3	76·0	75·7	75·4	75·1	74·8	74·5	74·2	73·9	73·7	73·4	58	95·53
82·0	81·7	81·4	81·1	80·8	80·5	80·2	79·9	79·6	79·3	79·1	78·8	78·5	78·2	77·9	77·6	77·3	77·0	76·7	76·4	76·1	75·8	75·5	75·2	74·9	74·6	59	97·17
83·4	83·1	82·8	82·5	82·2	81·9	81·6	81·3	81·0	80·7	80·4	80·1	79·8	79·5	79·2	78·9	78·6	78·3	78·0	77·7	77·4	77·1	76·8	76·5	76·2	75·9	60	98·82
84·8	84·5	84·2	83·9	83·6	83·3	83·0	82·6	82·3	82·0	81·7	81·4	81·1	80·8	80·5	80·2	79·9	79·6	79·3	79·0	78·7	78·4	78·1	77·8	77·5	77·2	61	100·47
86·2	85·9	85·6	85·2	84·9	84·6	84·3	84·0	83·7	83·4	83·1	82·8	82·5	82·1	81·8	81·5	81·2	80·9	80·6	80·3	80·0	79·7	79·4	79·0	78·7	78·4	62	102·12
87·6	87·2	86·9	86·5	86·3	86·0	85·7	85·4	85·0	84·7	84·4	84·1	83·8	83·5	83·2	82·8	82·5	82·2	81·9	81·6	81·3	80·9	80·6	80·3	80·0	79·7	63	103·76
89·0	88·6	88·3	88·0	87·7	87·4	87·0	86·7	86·4	86·1	85·8	85·4	85·1	84·8	84·5	84·2	83·8	83·5	83·2	82·9	82·6	82·2	81·9	81·6	81·3	81·0	64	105·41
90·3	90·0	89·7	89·4	89·0	88·7	88·4	88·1	87·7	87·4	87·1	86·8	86·4	86·1	85·8	85·5	85·1	84·8	84·5	84·2	83·8	83·5	83·2	82·9	82·5	82·2	65	107·06
91·7	91·4	91·1	90·7	90·4	90·1	89·8	89·4	89·1	88·8	88·4	88·1	87·8	87·4	87·1	86·8	86·5	86·1	85·8	85·5	85·1	84·8	84·5	84·1	83·8	83·5	66	108·70

CLERGET'S TABLE FOR THE ANALYSES OF SACCHARINE SUBSTANCES—*continued.*

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.)																										Per ct. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B. gram.
93·1	92·8	92·5	92·1	91·8	91·4	91·1	90·8	90·4	90·1	89·8	89·4	89·1	88·8	88·4	88·1	87·8	87·4	87·1	86·8	86·4	86·1	85·8	85·4	85·1	84·8	67	110·35
94·5	94·2	93·8	93·5	93·2	92·8	92·5	92·1	91·8	91·5	91·1	90·8	90·4	90·1	89·8	89·4	89·1	88·7	88·4	88·1	87·7	87·4	87·0	86·7	86·4	86·0	68	112·00
95·9	95·6	95·2	94·9	94·5	94·1	93·8	93·5	93·1	92·8	92·5	92·1	91·8	91·4	91·1	90·7	90·4	90·0	89·7	89·3	89·0	88·7	88·3	88·0	87·6	87·3	69	113·64
97·3	96·9	96·6	96·2	95·9	95·5	95·2	94·8	94·5	94·1	93·8	93·4	93·1	92·7	92·4	92·0	91·7	91·3	91·0	90·6	90·3	89·9	89·6	89·2	88·9	88·5	70	115·29
98·7	98·3	98·0	97·6	97·3	96·9	96·6	96·2	95·8	95·5	95·1	94·8	94·4	94·1	93·7	93·4	93·0	92·6	92·3	91·9	91·6	91·2	90·9	90·5	90·2	89·8	71	116·94
100·1	99·7	99·4	99·0	98·6	98·3	97·9	97·6	97·2	96·8	96·5	96·1	95·8	95·4	95·0	94·7	94·3	94·0	93·6	93·2	92·9	92·5	92·2	91·8	91·4	91·1	72	118·59
101·5	101·1	100·7	100·4	100·0	99·6	99·3	98·9	98·5	98·2	97·8	97·4	97·1	96·7	96·4	96·0	95·6	95·3	94·9	94·5	94·2	93·8	93·4	93·1	92·7	92·3	73	120·23
102·9	102·5	102·1	101·7	101·4	101·0	100·6	100·3	99·9	99·5	99·2	98·8	98·4	98·0	97·7	97·3	96·9	96·6	96·2	95·8	95·5	95·1	94·7	94·3	94·0	93·6	74	121·88
104·2	103·9	103·5	103·1	102·7	102·4	102·0	101·6	101·2	100·9	100·5	100·1	99·7	99·4	99·0	98·6	98·2	97·9	97·5	97·1	96·7	96·4	96·0	95·6	95·2	94·9	75	123·53
105·6	105·3	104·9	104·5	104·1	103·7	103·4	103·0	102·6	102·2	101·8	101·5	101·1	100·7	100·3	99·9	99·6	99·2	98·8	98·4	98·0	97·7	97·3	96·9	96·5	96·1	76	125·17
107·0	106·6	106·3	105·9	105·5	105·1	104·7	104·3	103·9	103·6	103·2	102·8	102·4	102·0	101·6	101·2	100·9	100·5	100·1	99·7	99·3	98·9	98·6	98·2	97·8	97·4	77	126·82
108·4	108·0	107·6	107·2	106·9	106·5	106·1	105·7	105·3	104·9	104·5	104·1	103·7	103·3	103·0	102·6	102·2	101·8	101·4	101·0	100·6	100·2	99·8	99·4	99·1	98·7	78	128·47
109·8	109·4	109·0	108·6	108·2	107·8	107·4	107·0	106·6	106·2	105·9	105·5	105·1	104·7	104·3	103·9	103·5	103·1	102·7	102·3	101·9	101·5	101·1	100·7	100·3	99·9	79	130·12
111·2	110·8	110·4	110·0	109·6	109·2	108·8	108·4	108·0	107·6	107·2	106·8	106·4	106·0	105·6	105·2	104·8	104·4	104·0	103·6	103·2	102·8	102·4	102·0	101·6	101·2	80	131·76
112·6	112·2	111·8	111·4	111·0	110·6	110·2	109·7	109·3	108·9	108·5	108·1	107·7	107·3	106·9	106·5	106·1	105·7	105·3	104·9	104·6	104·1	103·7	103·2	102·9	102·5	81	133·41
114·0	113·6	113·2	112·7	112·3	111·9	111·5	111·1	110·7	110·3	109·9	109·5	109·1	108·6	108·2	107·8	107·4	107·0	106·6	106·2	105·9	105·4	105·0	104·5	104·1	103·7	82	135·06
115·4	114·9	114·5	114·1	113·7	113·3	112·9	112·5	112·0	111·6	111·2	110·8	110·4	110·0	109·6	109·1	108·7	108·3	107·9	107·5	107·2	106·6	106·2	105·8	105·4	105·0	83	136·70
116·8	116·3	115·9	115·5	115·1	114·7	114·2	113·8	113·4	113·0	112·6	112·1	111·7	111·3	110·9	110·5	110·0	109·6	109·2	108·8	108·5	107·9	107·5	107·1	106·7	106·3	84	138·35
118·1	117·7	117·3	116·9	116·4	116·0	115·6	115·2	114·7	114·3	113·9	113·5	113·0	112·6	112·2	111·8	111·3	110·9	110·5	110·1	109·7	109·2	108·8	108·4	107·9	107·5	85	140·00
119·5	119·1	118·7	118·2	117·8	117·4	117·0	116·5	116·1	115·7	115·2	114·8	114·4	113·9	113·5	113·1	112·7	112·2	111·8	111·4	111·0	110·5	110·1	109·6	109·2	108·8	86	141·65
120·9	120·5	120·1	119·6	119·2	118·7	118·3	117·9	117·4	117·0	116·6	116·1	115·7	115·3	114·8	114·4	114·0	113·5	113·1	112·7	112·3	111·8	111·4	110·9	110·5	110·0	87	143·29
122·3	121·9	121·4	121·0	120·6	120·1	119·7	119·2	118·8	118·4	117·9	117·5	117·0	116·6	116·2	115·7	115·3	114·8	114·4	114·0	113·6	113·1	112·6	112·2	111·8	111·3	88	144·94
123·7	123·2	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·8	118·4	117·9	117·5	117·0	116·6	116·1	115·7	115·2	114·9	114·4	113·9	113·5	113·0	112·6	89	146·59
125·1	124·6	124·2	123·7	123·3	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·8	118·3	117·9	117·4	117·0	116·5	116·2	115·6	115·2	114·7	114·3	113·9	90	148·23
126·5	126·0	125·6	125·1	124·7	124·2	123·8	123·3	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·7	118·3	117·8	117·5	116·9	116·5	116·0	115·6	115·1	91	149·88
127·9	127·4	127·0	126·5	126·0	125·6	125·1	124·7	124·2	123·7	123·3	122·8	122·4	121·9	121·4	121·0	120·5	120·1	119·6	119·1	118·8	118·2	117·8	117·3	116·8	116·4	92	151·53
129·3	128·8	128·3	127·9	127·4	126·9	126·5	126·0	125·5	125·1	124·6	124·1	123·7	123·2	122·8	122·3	121·8	121·4	120·9	120·4	120·1	119·5	119·0	118·6	118·1	117·6	93	153·18
130·7	130·2	129·7	129·2	128·8	128·3	127·8	127·4	126·9	126·4	126·0	125·5	125·0	124·5	124·1	123·6	123·1	122·7	122·2	121·7	121·4	120·8	120·3	119·8	119·4	118·9	94	154·82
132·0	131·6	131·1	130·6	130·1	129·7	129·2	128·7	128·2	127·8	127·3	126·8	126·3	125·9	125·4	124·9	124·4	124·0	123·5	123·0	122·6	122·1	121·6	121·1	120·6	120·2	95	156·47
133·4	133·0	132·5	132·0	131·5	131·0	130·6	130·1	129·6	129·1	128·6	128·2	127·7	127·2	126·7	126·2	125·8	125·3	124·8	124·3	123·9	123·4	122·9	122·4	121·9	121·4	96	158·12
134·8	134·3	133·9	133·4	132·9	132·4	131·9	131·4	130·9	130·5	130·0	129·5	129·0	128·5	128·0	127·5	127·1	126·6	126·1	125·6	125·2	124·6	124·2	123·7	123·2	122·7	97	159·76
136·2	135·7	135·2	134·7	134·3	133·8	133·3	132·8	132·3	131·8	131·3	130·8	130·3	129·8	129·4	128·9	128·4	127·9	127·4	126·9	126·5	125·9	125·4	124·9	124·5	124·0	98	161·41
137·6	137·1	136·6	136·1	135·6	135·1	134·6	134·1	133·6	133·1	132·7	132·2	131·7	131·2	130·7	130·2	129·7	129·2	128·7	128·2	127·8	127·2	126·7	126·2	125·7	125·2	99	163·06
139·0	138·5	138·0	137·5	137·0	136·5	136·0	135·5	135·0	134·5	134·0	133·5	133·0	132·5	132·0	131·5	131·0	130·5	130·0	129·5	129·0	128·5	128·0	127·5	127·0	126·5	100	164·71

Cane- and Beet-Juice.—In the ordinary average work of the factory, the percentage of sugar present in the juice being treated is determined mainly by means of the saccharometer, according to the following tables :—

TABLE SHOWING THE RELATION OF PERCENTAGES, SPECIFIC GRAVITIES, AND DEGREES BAUMÉ IN CANE-SUGAR SOLUTIONS.

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
0·0	1·0000	0·0	6·2	1·0245	3·4	12·4	1·0502	6·9	18·6	1·0770	10·3
·1	1·0003	0·06	·3	1·0249	3·5	·5	1·0506	6·9	·7	1·0775	10·35
·2	1·0007	0·11	·4	1·0253	3·6	·6	1·0510	7·0	·8	1·0779	10·4
·3	1·0011	0·17	·5	1·0257	3·6	·7	1·0514	7·05	·9	1·0783	10·5
·4	1·0015	0·22	·6	1·0261	3·7	·8	1·0519	7·1	19·0	1·0788	10·5
·5	1·0019	0·28	·7	1·0265	3·7	·9	1·0523	7·2	·1	1·0792	10·6
·6	1·0023	0·33	·8	1·0269	3·8	13·0	1·0527	7·2	·2	1·0797	10·6
·7	1·0027	0·39	·9	1·0273	3·8	·1	1·0531	7·3	·3	1·0801	10·7
·8	1·0031	0·44	7·0	1·0277	3·9	·2	1·0536	7·3	·4	1·0806	10·7
·9	1·0034	0·5	·1	1·0281	3·9	·3	1·0540	7·4	·5	1·0810	10·8
1·0	1·0038	0·55	·2	1·0286	4·0	·4	1·0544	7·4	·6	1·0815	10·85
·1	1·0042	0·6	·3	1·0290	4·1	·5	1·0548	7·5	·7	1·0819	10·9
·2	1·0046	0·7	·4	1·0294	4·1	·6	1·0553	7·5	·8	1·0824	11·0
·3	1·0050	0·7	·5	1·0298	4·2	·7	1·0557	7·6	·9	1·0828	11·0
·4	1·0054	0·8	·6	1·0302	4·2	·8	1·0561	7·65	20·0	1·0832	11·1
·5	1·0058	0·8	·7	1·0306	4·3	·9	1·0566	7·7	·1	1·0837	11·1
·6	1·0062	0·9	·8	1·0310	4·3	14·0	1·0570	7·8	·2	1·0841	11·2
·7	1·0066	0·9	·9	1·0314	4·4	·1	1·0574	7·8	·3	1·0846	11·2
·8	1·0070	1·0	8·0	1·0318	4·4	·2	1·0578	7·9	·4	1·0850	11·3
·9	1·0074	1·05	·1	1·0322	4·5	·3	1·0583	7·9	·5	1·0855	11·3
2·0	1·0077	1·1	·2	1·0327	4·55	·4	1·0587	8·0	·6	1·0859	11·4
·1	1·0081	1·2	·3	1·0331	4·6	·5	1·0591	8·0	·7	1·0864	11·45
·2	1·0085	1·2	·4	1·0335	4·7	·6	1·0596	8·1	·8	1·0868	11·5
·3	1·0089	1·3	·5	1·0339	4·7	·7	1·0600	8·15	·9	1·0873	11·6
·4	1·0093	1·3	·6	1·0343	4·8	·8	1·0604	8·2	21·0	1·0877	11·6
·5	1·0097	1·4	·7	1·0347	4·8	·9	1·0609	8·3	·1	1·0882	11·7
·6	1·0101	1·4	·8	1·0351	4·9	15·0	1·0613	8·3	·2	1·0886	11·7
·7	1·0105	1·5	·9	1·0355	4·9	·1	1·0617	8·4	·3	1·0891	11·8
·8	1·0109	1·55	9·0	1·0359	5·0	·2	1·0621	8·4	·4	1·0895	11·8
·9	1·0113	1·6	·1	1·0364	5·05	·3	1·0626	8·5	·5	1·0900	11·9
3·0	1·0117	1·7	·2	1·0368	5·1	·4	1·0630	8·5	·6	1·0904	11·95
·1	1·0121	1·7	·3	1·0372	5·2	·5	1·0634	8·6	·7	1·0909	12·0
·2	1·0125	1·8	·4	1·0376	5·2	·6	1·0639	8·65	·8	1·0914	12·05
·3	1·0129	1·8	·5	1·0380	5·3	·7	1·0643	8·7	·9	1·0918	12·1
·4	1·0133	1·9	·6	1·0384	5·3	·8	1·0647	8·8	22·0	1·0923	12·2
·5	1·0137	1·9	·7	1·0388	5·4	·9	1·0652	8·8	·1	1·0927	12·2
·6	1·0141	2·0	·8	1·0393	5·4	16·0	1·0656	8·9	·2	1·0932	12·3
·7	1·0145	2·0	·9	1·0397	5·5	·1	1·0660	8·9	·3	1·0936	12·3
·8	1·0149	2·1	10·0	1·0401	5·55	·2	1·0665	9·0	·4	1·0941	12·4
·9	1·0153	2·2	·1	1·0405	5·6	·3	1·0669	9·0	·5	1·0945	12·4
4·0	1·0157	2·2	·2	1·0409	5·7	·4	1·0674	9·1	·6	1·0950	12·5
·1	1·0161	2·3	·3	1·0413	5·7	·5	1·0678	9·1	·7	1·0954	12·55
·2	1·0165	2·3	·4	1·0418	5·8	·6	1·0682	9·2	·8	1·0959	12·6
·3	1·0169	2·4	·5	1·0422	5·8	·7	1·0687	9·25	·9	1·0964	12·7
·4	1·0173	2·4	·6	1·0426	5·9	·8	1·0691	9·3	23·0	1·0968	12·7
·5	1·0177	2·5	·7	1·0430	5·9	·9	1·0695	9·4	·1	1·0973	12·8
·6	1·0181	2·6	·8	1·0434	6·0	17·0	1·0700	9·4	·2	1·0977	12·8
·7	1·0185	2·6	·9	1·0439	6·05	·1	1·0704	9·5	·3	1·0982	12·9
·8	1·0189	2·7	11·0	1·0443	6·1	·2	1·0709	9·5	·4	1·0986	12·9
·9	1·0193	2·7	·1	1·0447	6·2	·3	1·0713	9·6	·5	1·0991	13·0
5·0	1·0197	2·8	·2	1·0451	6·2	·4	1·0717	9·6	·6	1·0996	13·0
·1	1·0201	2·8	·3	1·0455	6·3	·5	1·0722	9·7	·7	1·1000	13·1
·2	1·0205	2·9	·4	1·0459	6·3	·6	1·0726	9·75	·8	1·1005	13·15
·3	1·0209	2·9	·5	1·0464	6·4	·7	1·0730	9·8	·9	1·1009	13·2
·4	1·0213	3·0	·6	1·0468	6·4	·8	1·0735	9·9	24·0	1·1014	13·3
·5	1·0217	3·0	·7	1·0472	6·5	·9	1·0739	9·9	·1	1·1019	13·3
·6	1·0221	3·1	·8	1·0476	6·55	18·0	1·0744	10·0	·2	1·1023	13·4
·7	1·0225	3·2	·9	1·0481	6·6	·1	1·0748	10·0	·3	1·1028	13·4
·8	1·0229	3·2	12·0	1·0485	6·7	·2	1·0753	10·1	·4	1·1032	13·5
·9	1·0233	3·3	·1	1·0489	6·7	·3	1·0757	10·1	·5	1·1037	13·5
6·0	1·0237	3·3	·2	1·0493	6·8	·4	1·0761	10·2	·6	1·1042	13·6
·1	1·0241	3·4	·3	1·0497	6·8	·5	1·0766	10·2	·7	1·1046	13·6

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
24·8	1·1051	13·7	31·6	1·1374	17·4	38·4	1·1712	21·05	45·2	1·2067	24·7
·9	1·1056	13·75	·7	1·1378	17·4	·5	1·1717	21·1	·3	1·2072	24·7
25·0	1·1060	13·8	·8	1·1383	17·5	·6	1·1722	21·15	·4	1·2077	24·8
·1	1·1065	13·9	·9	1·1388	17·55	·7	1·1727	21·2	·5	1·2083	24·8
·2	1·1070	13·9	32·0	1·1393	17·6	·8	1·1732	21·3	·6	1·2088	24·9
·3	1·1074	14·0	·1	1·1398	17·7	·9	1·1737	21·3	·7	1·2093	24·9
·4	1·1079	14·0	·2	1·1403	17·7	39·0	1·1743	21·4	·8	1·2099	25·0
·5	1·1083	14·1	·3	1·1408	17·8	·1	1·1748	21·4	·9	1·2104	25·0
·6	1·1088	14·1	·4	1·1412	17·8	·2	1·1753	21·5	46·0	1·2110	25·1
·7	1·1093	14·2	·5	1·1417	17·9	·3	1·1758	21·5	·1	1·2115	25·1
·8	1·1097	14·2	·6	1·1422	17·9	·4	1·1763	21·6	·2	1·2120	25·2
·9	1·1102	14·3	·7	1·1427	18·0	·5	1·1768	21·6	·3	1·2126	25·2
26·0	1·1107	14·35	·8	1·1432	18·0	·6	1·1773	21·7	·4	1·2131	25·3
·1	1·1111	14·4	·9	1·1437	18·1	·7	1·1778	21·7	·5	1·2136	25·35
·2	1·1116	14·5	33·0	1·1442	18·15	·8	1·1784	21·8	·6	1·2142	25·4
·3	1·1121	14·5	·1	1·1447	18·2	·9	1·1789	21·85	·7	1·2147	25·45
·4	1·1125	14·6	·2	1·1452	18·25	40·0	1·1794	21·9	·8	1·2153	25·5
·5	1·1130	14·6	·3	1·1457	18·3	·1	1·1799	22·0	·9	1·2158	25·6
·6	1·1135	14·7	·4	1·1462	18·4	·2	1·1804	22·0	47·0	1·2163	25·6
·7	1·1140	14·7	·5	1·1466	18·4	·3	1·1809	22·1	·1	1·2169	25·7
·8	1·1144	14·8	·6	1·1471	18·5	·4	1·1815	22·1	·2	1·2174	25·7
·9	1·1149	14·8	·7	1·1476	18·5	·5	1·1820	22·2	·3	1·2180	25·8
27·0	1·1154	14·9	·8	1·1481	18·6	·6	1·1825	22·2	·4	1·2185	25·8
·1	1·1158	14·9	·9	1·1486	18·6	·7	1·1830	22·3	·5	1·2191	25·9
·2	1·1163	15·0	34·0	1·1491	18·7	·8	1·1835	22·3	·6	1·2196	25·9
·3	1·1168	15·1	·1	1·1496	18·7	·9	1·1840	22·4	·7	1·2201	26·0
·4	1·1172	15·1	·2	1·1501	18·8	41·0	1·1846	22·4	·8	1·2207	26·0
·5	1·1177	15·2	·3	1·1506	18·85	·1	1·1851	22·5	·9	1·2212	26·1
·6	1·1182	15·2	·4	1·1511	18·9	·2	1·1856	22·5	48·0	1·2218	26·1
·7	1·1187	15·3	·5	1·1516	18·95	·3	1·1861	22·6	·1	1·2223	26·2
·8	1·1191	15·3	·6	1·1521	19·0	·4	1·1866	22·65	·2	1·2229	26·2
·9	1·1196	15·4	·7	1·1526	19·1	·5	1·1872	22·7	·3	1·2234	26·3
28·0	1·1201	15·4	·8	1·1531	19·1	·6	1·1877	22·75	·4	1·2240	26·35
·1	1·1206	15·5	·9	1·1536	19·2	·7	1·1882	22·8	·5	1·2245	26·4
·2	1·1210	15·55	35·0	1·1541	19·2	·8	1·1887	22·9	·6	1·2250	26·45
·3	1·1215	15·6	·1	1·1540	19·3	9	1·1892	22·9	·7	1·2256	26·5
·4	1·1220	15·7	·2	1·1551	19·3	42·0	1·1898	23·0	·8	1·2261	26·6
·5	1·1225	15·7	·3	1·1556	19·4	·1	1·1903	23·0	·9	1·2267	26·6
·6	1·1229	15·8	·4	1·1561	19·4	·2	1·1908	23·1	49·0	1·2272	26·7
·7	1·1234	15·8	·5	1·1566	19·5	·3	1·1913	23·1	·1	1·2278	26·7
·8	1·1239	15·9	·6	1·1571	19·55	·4	1·1919	23·2	·2	1·2283	26·8
·9	1·1244	15·9	·7	1·1576	19·6	·5	1·1924	23·2	·3	1·2289	26·8
29·0	1·1248	16·0	·8	1·1581	19·65	·6	1·1929	23·3	·4	1·2294	26·9
·1	1·1253	16·0	·9	1·1586	19·7	·7	1·1934	23·3	·5	1·2300	26·9
·2	1·1258	16·1	36·0	1·1591	19·8	·8	1·1940	23·4	·6	1·2305	27·0
·3	1·1263	16·1	·1	1·1596	19·8	·9	1·1945	23·45	·7	1·2311	27·0
·4	1·1267	16·2	·2	1·1601	19·9	43·0	1·1950	23·5	·8	1·2316	27·1
·5	1·1272	16·25	·3	1·1606	19·9	·1	1·1955	23·55	·9	1·2322	27·1
·6	1·1277	16·3	·4	1·1611	20·0	·2	1·1961	23·6	50·0	1·2327	27·2
·7	1·1282	16·4	·5	1·1616	20·0	·3	1·1966	23·7	·1	1·2333	27·2
·8	1·1287	16·4	·6	1·1621	20·1	·4	1·1971	23·7	·2	1·2338	27·3
·9	1·1291	16·5	·7	1·1626	20·1	·5	1·1976	23·8	·3	1·2344	27·3
30·0	1·1296	16·5	·8	1·1631	20·2	·6	1·1982	23·8	·4	1·2349	27·4
·1	1·1301	16·6	·9	1·1636	20·2	·7	1·1987	23·9	·5	1·2355	27·45
·2	1·1306	16·6	37·0	1·1641	20·3	·8	1·1992	23·9	·6	1·2361	27·5
·3	1·1311	16·7	·1	1·1646	20·35	·9	1·1998	24·0	·7	1·2366	27·55
·4	1·1315	16·7	·2	1·1651	20·4	44·0	1·2003	24·0	·8	1·2372	27·6
·5	1·1320	16·8	·3	1·1656	20·5	·1	1·2008	24·1	·9	1·2377	27·7
·6	1·1325	16·85	·4	1·1661	20·5	·2	1·2013	24·1	51·0	1·2383	27·7
·7	1·1330	16·9	·5	1·1666	20·6	·3	1·2019	24·2	·1	1·2388	27·8
·8	1·1335	17·0	·6	1·1671	20·6	·4	1·2024	24·2	·2	1·2394	27·8
·9	1·1340	17·0	·7	1·1676	20·7	·5	1·2029	24·3	·3	1·2399	27·9
31·0	1·1344	17·1	·8	1·1681	20·7	·6	1·2035	24·35	·4	1·2405	27·9
·1	1·1349	17·1	·9	1·1686	20·8	·7	1·2040	24·4	·5	1·2411	28·0
·2	1·1354	17·2	38·0	1·1692	20·8	·8	1·2045	24·45	·6	1·2416	28·0
·3	1·1359	17·2	·1	1·1697	20·9	·9	1·2051	24·5	·7	1·2422	28·1
·4	1·1364	17·3	·2	1·1702	20·9	45·0	1·2056	24·6	·8	1·2427	28·1
·5	1·1369	17·3	·3	1·1707	21·0	·1	1·2061	24·6	·9	1·2433	28·2

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
52·0	1·2439	28·2	58·8	1·2828	31·7	65·6	1·3235	35·2	72·4	1·3661	38·5
·1	1·2444	28·3	·9	1·2834	31·8	·7	1·3241	35·25	·5	1·3667	38·6
·2	1·2450	28·3	59·0	1·2840	31·85	·8	1·3247	35·3	·6	1·3674	38·6
·3	1·2455	28·4	·1	1·2845	31·9	·9	1·3253	35·35	·7	1·3680	38·7
·4	1·2461	28·4	·2	1·2851	31·95	66·0	1·3260	35·4	·8	1·3687	38·7
·5	1·2467	28·5	·3	1·2857	32·0	·1	1·3266	35·4	·9	1·3693	38·8
·6	1·2472	28·5	·4	1·2863	32·05	·2	1·3272	35·5	73·0	1·3699	38·8
·7	1·2478	28·6	·5	1·2869	32·1	·3	1·3278	35·5	·1	1·3705	38·9
·8	1·2483	28·65	·6	1·2875	32·15	·4	1·3285	35·6	·2	1·3712	38·9
·9	1·2489	28·7	·7	1·2881	32·2	·5	1·3291	35·6	·3	1·3719	39·0
53·0	1·2495	28·75	·8	1·2887	32·3	·6	1·3297	35·7	·4	1·3725	39·0
·1	1·2500	28·8	·9	1·2893	32·3	·7	1·3303	35·7	·5	1·3732	39·1
·2	1·2506	28·85	60·0	1·2898	32·4	·8	1·3309	35·8	·6	1·3738	39·1
·3	1·2512	28·9	·1	1·2904	32·4	·9	1·3315	35·8	·7	1·3745	39·2
·4	1·2517	28·9	·2	1·2910	32·5	67·0	1·3322	35·9	·8	1·3751	39·2
·5	1·2523	29·0	·3	1·2916	32·5	·1	1·3327	35·9	·9	1·3757	39·3
·6	1·2529	29·1	·4	1·2922	32·6	·2	1·3334	36·0	74·0	1·3764	39·3
·7	1·2534	29·1	·5	1·2928	32·6	·3	1·3340	36·0	·1	1·3770	39·4
·8	1·2540	29·2	·6	1·2934	32·7	·4	1·3346	36·1	·2	1·3777	39·4
·9	1·2546	29·2	·7	1·2940	32·7	·5	1·3352	36·1	·3	1·3783	39·5
54·0	1·2551	29·3	·8	1·2946	32·8	·6	1·3359	36·2	·4	1·3790	39·5
·1	1·2557	29·3	·9	1·2952	32·8	·7	1·3365	36·2	·5	1·3796	39·6
·2	1·2563	29·4	61·0	1·2958	32·9	·8	1·3371	36·3	·6	1·3803	39·6
·3	1·2568	29·4	·1	1·2964	32·9	·9	1·3377	36·3	·7	1·3809	39·7
·4	1·2574	29·5	·2	1·2970	33·0	68·0	1·3384	36·4	·8	1·3816	39·7
·5	1·2580	29·5	·3	1·2975	33·0	·1	1·3390	36·4	·9	1·3822	39·8
·6	1·2585	29·6	·4	1·2981	33·1	·2	1·3396	36·5	75·0	1·3828	39·8
·7	1·2591	29·6	·5	1·2987	33·1	·3	1·3402	36·5	·1	1·3835	39·9
·8	1·2597	29·7	·6	1·2993	33·2	·4	1·3408	36·6	·2	1·3842	39·9
·9	1·2602	29·7	·7	1·2999	33·2	·5	1·3415	36·6	·3	1·3848	40·0
55·0	1·2608	29·8	·8	1·3005	33·3	·6	1·3421	36·7	·4	1·3855	40·0
·1	1·2614	29·8	·9	1·3011	33·3	·7	1·3427	36·7	·5	1·3861	40·1
·2	1·2620	29·9	62·0	1·3017	33·4	·8	1·3433	36·8	·6	1·3868	40·1
·3	1·2625	29·9	·1	1·3023	33·4	·9	1·3440	36·8	·7	1·3874	40·2
·4	1·2631	30·0	·2	1·3029	33·5	69·0	1·3446	36·9	·8	1·3880	40·2
·5	1·2637	30·05	·3	1·3035	33·5	·1	1·3452	36·9	·9	1·3887	40·3
·6	1·2642	30·1	·4	1·3041	33·6	·2	1·3458	37·0	76·0	1·3894	40·3
·7	1·2648	30·15	·5	1·3047	33·6	·3	1·3465	37·0	·1	1·3900	40·4
·8	1·7654	30·2	·6	1·3053	33·7	·4	1·3471	37·1	·2	1·3907	40·4
·9	1·2660	30·25	·7	1·3059	33·7	·5	1·3477	37·1	·3	1·3913	40·5
56·0	1·2665	30·3	·8	1·3065	33·8	·6	1·3484	37·2	·4	1·3920	40·5
·1	1·2671	30·4	·9	1·3071	33·8	·7	1·3490	37·2	·5	1·3926	40·6
·2	1·2677	30·4	63·0	1·3077	33·9	·8	1·3496	37·3	·6	1·3933	40·6
·3	1·2683	30·5	·1	1·3083	33·9	·9	1·3502	37·3	·7	1·3940	40·7
·4	1·2688	30·5	·2	1·3085	34·0	70·0	1·3509	37·4	·8	1·3946	40·7
·5	1·2694	30·6	·3	1·3095	34·0	·1	1·3515	37·4	·9	1·3953	40·8
·6	1·2700	30·6	·4	1·3101	34·1	·2	1·3521	37·5	77·0	1·3959	40·8
·7	1·2706	30·7	·5	1·3107	34·1	·3	1·3528	37·5	·1	1·3966	40·8
·8	1·2712	30·7	·6	1·3113	34·2	·4	1·3534	37·6	·2	1·3972	40·9
·9	1·2717	30·8	·7	1·3119	34·2	·5	1·3540	37·6	·3	1·3979	41·0
57·0	1·2723	30·8	·8	1·3126	34·3	·6	1·3546	37·7	·4	1·3986	41·0
·1	1·2729	30·9	·9	1·3132	34·3	·7	1·3553	37·7	·5	1·3992	41·0
·2	1·2735	30·9	64·0	1·3138	34·4	·8	1·3559	37·8	·6	1·3999	41·1
·3	1·2740	31·0	·1	1·3144	34·4	·9	1·3565	37·8	·7	1·4005	41·1
·4	1·2746	31·0	·2	1·3150	34·5	71·0	1·3572	37·9	·8	1·4012	41·2
·5	1·2752	31·1	·3	1·3156	34·5	·1	1·3578	37·9	·9	1·4019	41·2
·6	1·2758	31·1	·4	1·3162	34·6	·2	1·3585	38·0	78·0	1·4025	41·3
·7	1·2764	31·2	·5	1·3168	34·6	·3	1·3591	38·0	·1	1·4032	41·3
·8	1·2769	31·2	·6	1·3174	34·7	·4	1·3597	38·1	·2	1·4039	41·4
·9	1·2775	31·3	·7	1·3180	34·7	·5	1·3604	38·1	·3	1·4045	41·4
58·0	1·2781	31·3	·8	1·3186	34·8	·6	1·3610	38·2	·4	1·4052	41·5
·1	1·2787	31·4	·9	1·3192	34·8	·7	1·3616	38·2	·5	1·4058	41·5
·2	1·2793	31·4	65·0	1·3198	34·9	·8	1·3623	38·2	·6	1·4065	41·6
·3	1·2799	31·5	·1	1·3205	34·95	·9	1·3629	38·3	·7	1·4072	41·6
·4	1·2804	31·5	·2	1·3211	35·0	72·0	1·3635	38·3	·8	1·4078	41·7
·5	1·2810	31·6	·3	1·3217	35·05	·1	1·3642	38·4	·9	1·4085	41·7
·6	1·2816	31·6	·4	1·3223	35·1	·2	1·3648	38·4	79·0	1·4092	41·8
·7	1·2822	31·7	·5	1·3229	35·15	·3	1·3655	38·5	·1	1·4098	41·8

Table showing the Relation of Percentages, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
79·2	1·4105	41·9	81·0	1·4226	42·7	82·7	1·4341	43·5	84·4	1·4457	44·3
·3	1·4112	41·9	·1	1·4232	42·8	·8	1·4348	43·6	·5	1·4464	44·4
·4	1·4119	42·0	·2	1·4239	42·8	·9	1·4354	43·6	·6	1·4471	44·4
·5	1·4125	42·0	·3	1·4246	42·9	83·0	1·4361	43·7	·7	1·4478	44·5
·6	1·4132	42·1	·4	1·4253	42·9	·1	1·4368	43·7	·8	1·4485	44·5
·7	1·4138	42·1	·5	1·4259	43·0	·2	1·4375	43·8	·9	1·4492	44·6
·8	1·4145	42·2	·6	1·4266	43·0	·3	1·4382	43·8	85·0	1·4498	44·6
·9	1·4152	42·2	·7	1·4273	43·1	·4	1·4388	43·9	·1	1·4505	44·7
80·0	1·4158	42·2	·8	1·4280	43·1	·5	1·4395	43·9	·2	1·4512	44·7
·1	1·4165	42·3	·9	1·4287	43·2	·6	1·4402	44·0	·3	1·4519	44·8
·2	1·4172	42·3	82·0	1·4293	43·2	·7	1·4409	44·0	·4	1·4526	44·8
·3	1·4179	42·4	·1	1·4300	43·3	·8	1·4416	44·1	·5	1·4533	44·9
·4	1·4185	42·4	·2	1·4307	43·3	·9	1·4423	44·1	·6	1·4540	44·9
·5	1·4192	42·5	·3	1·4314	43·4	84·0	1·4430	44·2	·7	1·4547	45·0
·6	1·4199	42·5	·4	1·4320	43·4	·1	1·4437	44·2	·8	1·4554	45·0
·7	1·4205	42·6	·5	1·4327	43·5	·2	1·4443	44·3	·9	1·4561	45·1
·8	1·4212	42·6	·6	1·4334	43·5	·3	1·4450	44·3	86·0	1·4568	45·1
·9	1·4219	42·7									

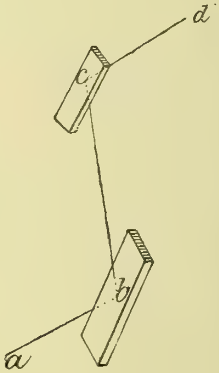
The preceding table gives the proportions of sugar present in the juice as indicated by the sp. gr. or the degrees B. of the solution. The B. degrees are more frequently used in sugar-factories than the actual sp. gr., and this table gives the data for the comparison between the two. In either case, the sp. gr. or B. may be determined by the sp. gr. bottle or the hydrometer spindle, and if the usual precautions are taken, the results are directly comparable. The sp. gr. bottle is of course the more correct method of the two. When still greater accuracy is necessary, the juice has to be treated in a similar way to that in which the solutions of sugar have already been directed to be treated, viz. 16·35 *cc.* of the juice are measured into a 100-*cc.* flask, subacetate of lead is added, and if necessary sulphite of soda, the solution is made up to 100 *cc.*, and, after admixture, filtered and polarized, as before directed. Cane- and beet-juice require a larger addition of basic acetate of lead, on account of the gummy and mucilaginous matters which they contain.

Beet Analysis.—The analysis of beet-juice is like that of beet-sugar. When beet itself is to be analysed, special precautions have to be taken, in order to obtain a fair sample. It is necessary to wash free from mechanical impurities, and to remove the top and small rootlets, and then dry the root. Occasionally it is desirable to determine the difference of weight in the root before and after this treatment, as the amount of mechanical impurities may be excessive. This is not often the case. To obtain a fair sample of the produce of a field, it is absolutely essential to take a considerable number of roots, which should be selected so as to differ in size and outward appearance. It is sometimes more satisfactory to sample the roots by taking a large boring out of each by means of an instrument similar to a cheese-taster. The whole of the samples taken out must then be sliced, shredded, and mixed, and an average sample taken for analysis. It is generally recommended that the estimation of the sugar in the root should be taken by pulping a large weight (200–300 *grm.*) of the cores cut out from the roots, and pressing them so as to express the juice in a small filter-press or filter-bag. This appears to involve a considerable risk of error, inasmuch as the pulping cannot be effectual without a certain loss of juice, which is of considerable importance in a small sample such as that worked upon. It seems far preferable to pulp a portion of the sample (not less than 100 *grm.*), transfer it to a piece of thin muslin tied up so as to form a bag, and boil for one or two minutes in a beaker or other suitable vessel, withdrawing the bag and squeezing out the superfluous liquid, decanting the total liquid into another vessel, and repeating the operation in the same way 3–5 times, as may be necessary, boiling the residue in the last instance for 5–10 minutes, so as to remove as far as possible the last residue of soluble matters, and, after squeezing, rinsing the muslin bag containing the marc once more with water. A solution obtained in this way will necessarily be a dilute one, and if too dilute, it will be requisite to concentrate it before titrating for glucose, or using for the estimation of cane-sugar. If so, the concentration must be effected by slow evaporation on the water bath, so as not to convert any of the cane-sugar into glucose. After concentration, the analysis is carried out as before directed.

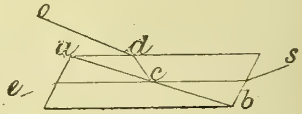
Sugar-cane Analysis.—A correct estimation of the amount of sugar obtainable from sugar-canes is even more difficult than in the case of beet-roots; the best plan to be pursued is unquestionably as follows. Obtain a true sample of the canes of not less than 4–6 lb. in weight, but drawn in such a way as to obtain a fair proportion of the joints in the canes, so as to faithfully represent the whole of the sample itself. Slice the canes longitudinally with a sharp knife, making at least 3 or 4 cuts, so as to divide them into narrow pieces or slips not more than $\frac{1}{2}$–$\frac{5}{8}$ in. diam. Pass these pieces between the rollers of a hand roller-press provided with a tray underneath and a spout to carry away the liquid which is pressed out. After passing the pieces through twice, increasing the pressure on the second occasion, dip them into hot water for a few seconds, so as to moisten them, and pass again through the press 2 or 3 times, still increasing the pressure each time. The begass or trash brought out should not contain more than about 15 per cent. of moisture, if the operation has been properly performed. When this has been done, the liquid pressed out is in a state fit for analysis, and this may be carried through at once on the liquid, calculations being made on the dry material, i. e. the sugar-cane originally put into the press.

Determination of Sugars—Optical Methods—Polarized Light.—When a ray of light *a b* (Fig. 1413) falls upon a polished surface of glass or other non-metallic substance, inclined to an angle of 35° 20′, the reflected ray is altered in character, and acquires peculiar properties: it is in fact said to be "polarized." In order to show the character of the change which has been produced in the ray of light, the polarized ray may be received at *c* upon a second reflecting surface fixed at the same angle to the already reflected ray. If the two reflecting surfaces are parallel one to another, the polarized ray will be reflected again; but if the second reflector is rotated around the axis *c d* until the reflecting planes are perpendicular to each other, no light is reflected, and, at intermediate points in the rotation, the amount of reflection differs. If the angle *a b c* differs within moderate limits from 35° 20′, some portion of the light is polarized, but the maximum effect is obtained only at this angle. The angle, however, differs for different substances;—thus for water it is 36° 49′, and for quartz 32° 28′.

1413.



The light may also be polarized by refraction. Calc-spar and all other doubly-refracting crystals have the power of polarizing light. A ray of ordinary light passed through a crystal of calc-spar, in any direction except its optical axis, is divided into 2 beams of equal intensity, called the ordinary and extraordinary rays. By a suitable adjustment of the position of the prism, it is of course easy to throw the ordinary ray entirely out of the field of view of the optical instrument in which it is to be used, and if the extraordinary ray is then passed through a second rhomb of calc-spar, it experiences double refraction, giving rise to 2 beams of unequal intensity, and the 2 rays resulting from the double refraction are found to be polarized. Tourmaline, selenite, and other crystalline bodies, as well as glass, when submitted to strains or pressure, become double-refracting. A plane of polarized light is that in which the ray incident at the polarizing angle is reflected or transmitted in the greatest degree, and it is obvious that when the polarization has been produced by refraction, the plane of polarization is parallel to the plane of refraction.



1414.

The Nichol prism, which is probably the most valuable device used for producing polarized light, or analyzing it, consists of a rhomb of calc-spar slit along the plane passing through the shorter diagonal; the two halves are cemented together again with Canada-balsam, the refracting index of which is intermediate between that of the extraordinary and ordinary indices of the crystal. The result of this arrangement is that when the ray of light *s* (Fig. 1414) enters the prism, the ordinary ray is totally reflected on the surface of the internal layer of balsam *a b*, and is refracted out of the crystal in the direction *c d o*, while the extraordinary ray *c e* emerges alone in a direction not differing greatly from that of the principal axis of the crystal itself.

When a ray of light in which a state of circular polarization has been produced is refracted by a Nichol prism, and viewed through an analyzer, the rotation of the analyzer causes no variation in the intensity of the light; but this circular polarized light is not identical with ordinary light, as may be proved by interposing a plate of selenite in the course of the ray, when the light becomes elliptically polarized. Rotation of the plane of polarization of crystals of quartz or calc-spar causes a rotation of the polarization-plane around its axis. There are 2 varieties of quartz, known as right-handed and left-handed, one of which rotates the plane of polarization to the right, and the other to the left. If a plane of quartz cut perpendicularly to its axis is placed between the analyzer and the polarizer, the ray of polarized light is rotated, and, instead of being white, is coloured, the tints of colour changing in the order of the colours of the spectrum as the analyzer is turned. If monochromatic light is used instead of white light, it is found that when the Nichol prisms are adjusted so as to produce darkness, corresponding to total extinction of the ray of light, the introduction of the plate of quartz in the course of the ray partially restores the light, but total extinction is again produced on rotating the analyzer. The angular rotation which has been experienced by the ray may be measured by the degree to which it is necessary to rotate the analyzer to produce this effect.

Two facts must be borne in mind here. The angle of rotation is directly proportional to the thickness of the quartz, and it varies for the different rays of the spectrum, being greater for those rays which are more refrangible, as shown by the following table, which gives the rotations produced by a quartz plate 1 *mm.* thick:—

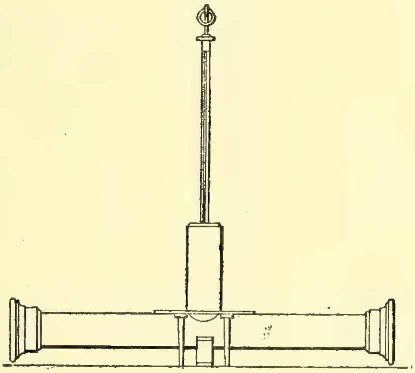
Red	19°	Blue	32°
Orange	21°	Indigo	36°
Yellow	23°	Violet	41°
Green	28°		

Polariscopes or Optical Saccharometers.—Solutions of cane-sugars as well as many other bodies possess the property of deviating the course of a ray of polarized light in a fixed and definite degree. Other sugars deviate the course of this ray to degrees which differ not only in amount but in direction. Thus cane-sugar and dextrose deviate the plane of rotation to the right, while lævulose and other sugars deviate it to the left. It has consequently been possible to construct instruments in which, by measuring the degree of rotation or deviation produced by a solution contained in a tube of a certain length, it is easy to determine the percentage of sugar present, because by numerous experiments it has been proved that the angular rotation produced by different sugars is directly proportional (within certain limits of error, controlled by well-understood circumstances) to the bodies present.

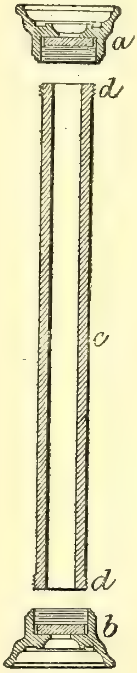
The " polariscopes," as they are called, i. e. optical saccharometers of different makers are here described. The three instruments in common use are the Soleil-Ventzke, Soleil-Duboscq, and Shadow (Penombre).

In construction, the Soleil polariscope is simple. The tube which contains the liquor consists of 3 parts (Fig. 1415), of which, 2 parts *a b* are capable of being screwed on to the remaining portion *c*, which consists of a glass tube encased in metal, the ends of the tube being carefully ground off to an exact length of 20 *centim.*, and provided with screws *d.* Two small flat pieces of glass are arranged to cover the ends of this tube, and these are secured in place by the caps *a b*, which are furnished with internal screws fitting on to the screws of the central part *c*. This provides for a column of liquid contained in the tube exactly 20 *centim.* long. Another tube of the same kind, but 22 *centim.* long, is requisite for use in those cases in which sugar solutions have to be inverted. This tube is preferably constructed as in Fig. 1416, with an outlet or T-piece rising from the centre of the tube, through which a thermometer can be passed to ascertain the exact temperature of the contents of the tube, the instrument being so arranged that this tube can be dropped in between the eye-piece and objective.

1416.



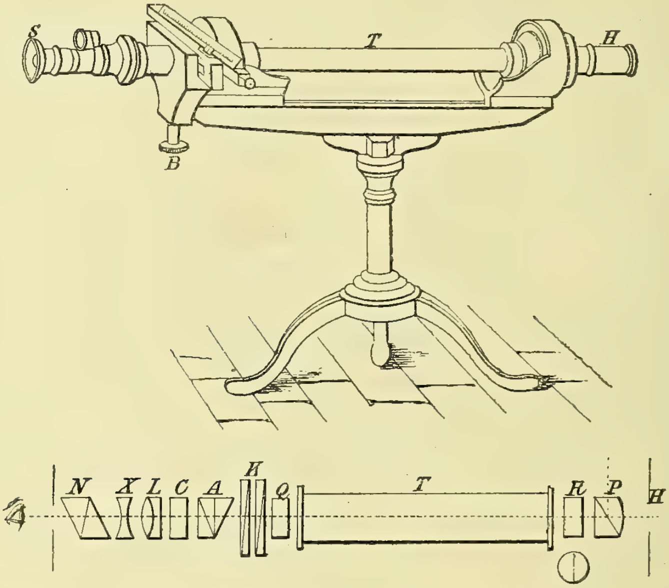
1415.



The instrument consists of 2 distinct portions, one designed to polarize the light, and the other to analyze or test the character of the ray of light passing through the solution contained in the tube, both of which are capable of rotation, the former, i. e. the objective, to a small extent only, and the latter through the complete circle. This latter portion of the instrument is, according to the character of the polariscope, furnished with a graduated circle for indicating the degree of rotation, or with a divided scale showing the thickness of the quartz, hereafter referred to, which has been introduced between the sugar solution and the eye. The optical part of the instrument, as well as its general form, is shown in Fig. 1417.

The Soleil-Duboscq polariscope consists of 2 metallic tubes mounted on a tripod. The light enters at H by a circular opening having a diameter of 3 *mm.*, and traverses the achromatic polarizing prism P. R is a plate of quartz called the plate of double rotation, composed of 2 half-discs of quartz of equal thickness, cut perpendicularly to the axis of crystallization, turned in opposite directions, and cemented together so that the plane of separation is in a vertical direction. The half-discs have contrary rotations, one being left-handed and the other right-handed. The light then passes on to the tube T containing the solution to be examined, and encounters Q, a quartz plate either right-handed or left-handed, of arbitrary thickness. From Q, the ray reaches K, which are wedge-shaped quartz plates having the same kind of rotation, but differing from that of Q. These are fixed in brass slides, covered with plain brass plates on each side, so as to protect them from injury. They are so fixed that they can be moved to and fro at will, and by this means the optical thickness of the quartz through which the polarized rays have to pass may be increased or diminished. The light then passes to the analyzer A and quartz plate C; a telescope X L defines the field of view of the instrument. The doubly-refracting prism N is placed relatively to the diaphragm of the telescope, in such a way that the passage of one of the rays transmitted by the polarizer is intercepted. Either the ordinary or the extraordinary ray, according to the thickness of the quartz-plate, will pass through. From the construction of this apparatus, it is evident that on making an observation through the ocular or eye-piece, there will appear a luminous disc with a vertical line in its centre, the latter being produced by the junction of the 2 quartz plates R. The sum of the thickness of the two prismatic quartz-plates at a certain position is exactly equal to that of Q, and as the rotations are different, one being right- and the other left-handed, it follows that they neutralize one another, and produce no change of colour on the polarized ray.

1417.



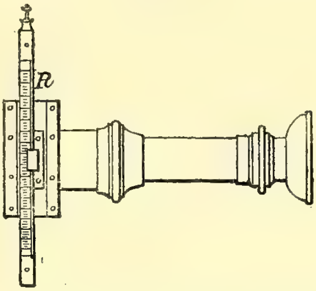
When the instrument is properly adjusted, and the tube filled with distilled water, each side of the field will be of the same colour. The tube containing the distilled water is now withdrawn, and another tube containing a liquid having a rotatory power which will act on polarized light is introduced. The uniformity of the colour will be destroyed, owing to the rotatory effect of the liquid itself, which vitiates the compensatory effects of the plate R and the quartz wedges.

The direction in which the ray of light is rotated will depend upon the character of the liquid. Thus with cane-sugar, the deviation will be to the right, and this, with that of the right-handed plate of quartz, produces an inequality in the polarizer, and consequently the production of unequal colour in the two halves of the field.

The only way to restore the field to uniformity is by turning the screw, by which the quartz-wedges are moved to and fro, whereby the thickness of the quartz is increased or diminished. This increase or diminution compensates for the deviating effect of the liquid, and shows the degree to which the ray of light has been rotated. The action of the compensator also shows whether the substance examined is right or left rotating.

The degree of rotation is measured by the thickness of quartz necessary to neutralize the deviation of the body examined. This thickness is estimated by a graduated scale fixed to one of the slides R (Fig. 1418), in such a way that the one carrying the scale is read off upon the other serving as an indicator.

1418.



In the instrument as ordinarily constructed, the scale is graduated into degrees indicating percentages of sugar on each side of the zero division.

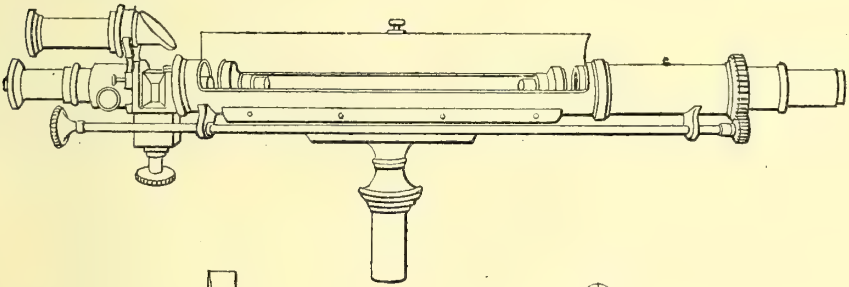
A thickness of quartz equal to $\frac{1}{100}$ *mm.* is equivalent to a displacement of 1 division on the scale, compensating a rotatory effect of 1 per cent. of sugar when the solution is made of the proper strength.

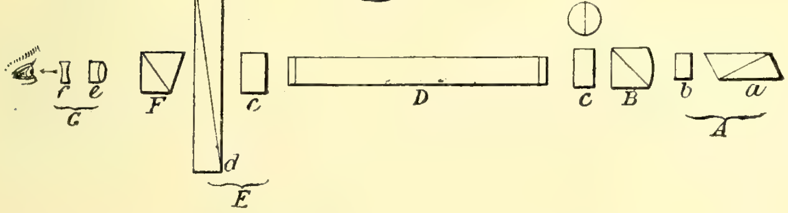
This polariscope has been greatly improved over its original form by placing in front of the ocular of the telescope a Nichol prism N capable of rotation. This arrangement is for the purpose of producing what is called the sensitive tints, i. e. that tint in which the change from one colour to another is most readily appreciated by the eye. The colour of the liquid under examination is to a considerable extent destroyed by this prism.

The zero point is determined by filling one of the tubes with distilled water, putting it into position, observing the reading, focussing, and then adjusting by means of the screw B.

Fig. 1419 gives a perspective view of the Soleil-Ventzke Saccharometer in its most improved form, and Fig. 1420 the section of the optical arrangement. A support standing on a tripod holds the main portion of the apparatus, the middle part of which consists of a metallic receptacle, provided with a hinged cover to prevent access of light while an observation is being taken. At each end of this support, a brass tube is fixed, one containing the double quartz plate *d* and the polarizer *c*. A is the regulator for changing the tints of the double quartz plates C. It consists of the Nichol prism *a* and quartz plates *b*, cut perpendicularly to the axis of the crystal, both of which can be caused to rotate by appropriate means. B, the polarizer, is an achromatic calc-spar prism. As its principal section is vertical, the extraordinary ray is totally reflected at the axis and only the ordinary ray is transmitted. The convex surface turned towards A renders the rays parallel. The double quartz plate C is precisely similar to that of the Soleil-Duboscq apparatus. Its thickness may be either 3·75 *mm.* or 7·50 *mm.* D is the observation tube. The compensator E

1419.



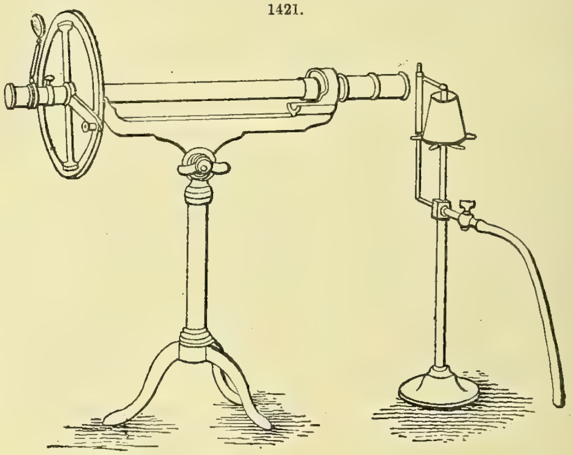


1420.

consists of the right-handed plate of quartz *c*, and the wedge-form plates *d*, which are left-handed, one being fixed and the other movable by means of a rack and pinion, to increase or diminish the thickness of crystal through which the polarized ray has to pass; *c* may be of left-handed quartz, but in that case the optical rotation of the wedges must be in an opposite sense. The analyzer F is an achromatic calc-spar prism, whose principal section must be parallel to that of the polarizer B when the thickness of the plate C is 3·75 *mm.*, or perpendicular to it when the latter is double that thickness. G is a small Galilean telescope, consisting of objective *e* and ocular *f*.

The Shadow polariscope is constructed as follows. It possesses certain peculiarities, the principal of which is that the field of the optical part of the instrument appears to the eye to be divided into two halves, one light and one dark (in shade, not tint or colour), divided by a vertical line, and the analyzer has to be rotated till the two portions of the field appear of the same shade. The apparatus was devised by Duboscq and Cornu, and is shown in Fig. 1421. The polarizing prism consists of a rhomb of calc-spar, divided longitudinally, following the plane of the smaller diagonal A B, as shown in Fig. 1422. Each of the cut faces being removed for an angle of 2½°, the remaining sections I B M and O B G are cemented together again on the planes passing through B I and B O. A double prism is produced by this means, the principal sections having an angle of 5°; the effect of this is that small changes in the illuminating field produce relatively large changes in rotation in the ray of polarized light, and the analyzer has to be rotated relatively to a large extent to neutralize the effect. This increases the delicacy of the instrument. If the prisms are not properly adjusted, they are rectified by turning the Nichol prism by means of a button, until the whole field becomes of a uniform slate or French-grey colour, and the zero of the scale exactly corresponds to that of the Vernier. When this is the case, the instrument is in proper adjustment, and ready for use.

1421.

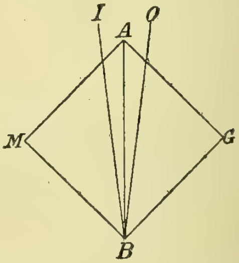


The observation is made in the same way as in the last polariscope mentioned, with the exception that the ocular analyzer is rotated instead of being moved in a transverse direction to the field of view.

In analyzing a sample, the arm is rotated until the field assumes a uniform tint, and the difference between the two sides of the field of view has disappeared, the vertical line alone remaining. At this point, the rotation is stopped, and the scale is read.

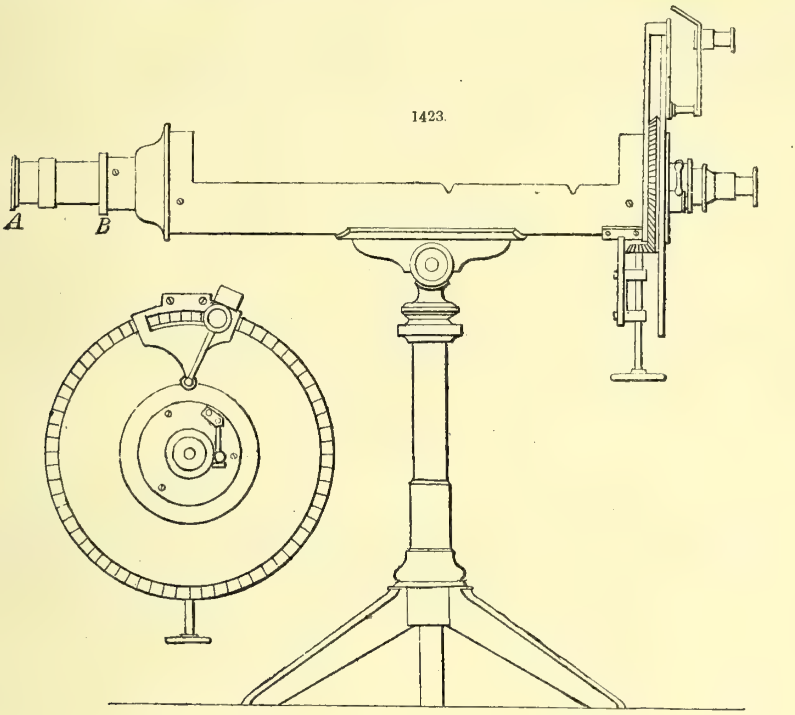
This polariscope is much employed in France. It is very accurate, moderate in price, and on the whole one of the most useful. A great advantage which it possesses is that persons who are wholly or partially colour-blind can read it with reasonable if not perfect accuracy. The light needed for it is monochromatic, and may be obtained by means of the Laurent lamp, or any other lamp which introduces a sodium compound into the flame of a Bunsen burner.

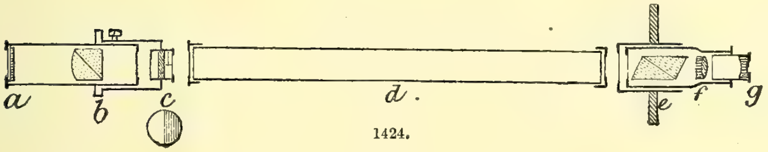
1422.



The optical parts of Laurent's polariscope differ considerably from those last described. Figs. 1423, 1424, show the construction of the apparatus; *a* is a thin plate of bichromate of potash, inserted to cut off any blue or violet rays in the sodium light which is used for the purpose, so as to render it more thoroughly monochromatic.

The polarizer *b* is a calc-spar prism, both parts being placed in a movable brass tube *a b* (Fig. 1424); *c* is a round diaphragm covered by a plate of glass, on which a thin section of quartz is cemented, the quartz being cut in such a way that only half the aperture is covered by it; *e* is the analyzing Nichol, and *f g* the lenses of the telescope. The theory of this saccharometer is as follows. Supposing the plane of polarization to be vertical to the optical axis of the quartz plate, the light will traverse it without deviation; if the analyzer is rotated, advance is made progressively to the maximum or total extinction of the light; consequently, by turning the analyzer through any given angle to the right, the plane of polarization being no longer parallel to the axis of the crystal, the polarized ray will pass without deviation on the right side on which there is no quartz, but it will be deviated on the left, and on this side there will be determined a principal section symmetrical to that of the polarizer on the right side, but turning to the left. If the analyzer be now turned until the principal section is perpendicular to that of the polarizer, there will be a total extinction of the light to the right, but only partial to the left. If, on the contrary, the principal section of the analyzer is perpendicular to that which corresponds to that of the quartz plate, there will be a total extinction to the left and partial to the right. Finally, if the principal section of the analyzer is intermediate in position, i. e. perpendicular to the axis of the crystal, or horizontal, there will be partial extinction of the light both to the right and left, and the luminous disc sighting the field of the instrument will appear uniformly obscured. Hence a small rotation of the analyzer tends to change the uniformity of the shade, and renders this polariscope specially delicate with small angles. The distinctive peculiarity of this instrument is that by turning A B (Fig. 1423), the angle of rotation is augmented, and by this means the field is greatly brightened, and observation may be made with darker solutions than can otherwise be used.


1423.



1424.

This polariscope has been adopted for use in the French Government laboratories for sugar analysis; although it is stated that recently some very considerable modifications have been made in it, mainly in the direction of working with observation-tubes of 1 or even 2 *m.* in length, and in the graduation so as to enable small proportions of sugar to be estimated more conveniently.

Specific Rotatory Power.—The peculiar tint called the "transition" tint (*teint de passage*) is produced when a ray of light is caused to pass through a quartz plate 3·75 *mm.* thick. The tint is perhaps best described as rose-purple of a somewhat delicate character, but it is easily altered by the slightest movement in the position of the analyzer. To most persons who are not colour-blind, this is a most delicate colour for detecting changes in the shades of tint produced by polarization.

The mode in which the specific rotatory power of liquids is measured is somewhat peculiar. It follows from what has been said that the rotation is directly proportionate to the length of the column of liquids through which the ray passes, and is also proportional, sometimes directly and sometimes indirectly, to the quantity of active substance dissolved in the liquid. If e be the amount of substance dissolved in a unit of weight of the solution, l the length of the liquid column, and a the observed angle of rotation for any particular column, at the transition tint the angle of rotation for the unit of length will be $\frac{a}{e\,l}$; but as the solution of the optically active body is often attended with alteration of volume, it is desirable, in order to obtain an expression independent of such irregularities, to refer the observed angle of deviation to a hypothetical unit of density—that is to divide the quantity $\frac{a}{e\,l}$ by the density g of the solution. The expression $[\alpha]\,j = \frac{a}{e\,l\,g}$ is called the specific rotatory power, and represents the angle of deviation which the pure substance in a column of the unit of length and density 1 would impart to the ray corresponding to the transition tint. For instance, a solution containing 0·155 *grm.* of cane-sugar to 1 *grm.* of liquid has a sp. gr. of 1·06, and deflects the polarized ray for the transition tint 24° in a tube 20 *mm.* long. The specific rotatory power is therefore

$$[\alpha]\,j = \frac{24}{155 \times 20 \times 1{\cdot}06} = 7{\cdot}3^\circ.$$

$[\alpha]$ is the expression for the specific rotatory power in general; a letter affixed shows the particular ray of the spectrum at which the deviation was observed, thus $[\alpha]$ D and $[\alpha]\ j$ are the expressions for the line D of the spectrum, and for the mean yellow ray or transition tint respectively. The minus sign is prefixed to the degree when the substance rotates to the left.

The following table shows the equivalence in degrees of different polariscopes:—

		Grm. Sugar in 100 *cc.*
1° Scale of Mitscherlich	=	·750
1° „ Soleil-Duboscq	=	·1619
1° „ Ventzke-Soleil	=	·26048
1° „ Wild (sugar scale)	=	·1000
1° „ Shadow sacchar. (of Laurent and Duboscq)	=	·1619

1° Mitscherlich = 4·635° Soleil-Duboscq.
1° „ = 2·879° Soleil-Ventzke.

1° Soleil-Duboscq = ·215° Mitscherlich.
1° „ „ = ·620° Ventzke-Soleil.
1° „ „ = 1·619° Wild.
1° „ Ventzke = ·346° Mitscherlich.
1° „ „ = 1·608° Soleil-Duboscq.
1° „ „ = 2·648° Wild.
1° Wild (sugar scale) = ·618° Soleil-Duboscq.
1° „ „ = ·384° Soleil-Ventzke.
1° „ „ = ·133° Mitscherlich.

Equivalence in Circular Degrees.—

Wild (sugar scale) 1° = ·1328 circ. degree D.
Soleil-Duboscq j 1° = ·2167 „ „ D.
„ „ j 1° = ·2450 „ „ j.

Soleil-Ventzke j 1° = ·3455 circ. degree D.
„ „ j 1° = ·3906 „ „ j.

Instruments reading angular degrees, such as Wild's, Laurent's and Duboscq's *saccharimètre à pénombre* may be made to give the concentration—i.e. the number of *grm.* of sugar in 100 *cc.* of solution—by the following formula

$$C = \frac{100\,a}{k\,[\alpha]\,D}$$

in which a is the observed angle of rotation, k the length of the observation-tube in decimetres, and $[\alpha]$ D the specific rotatory power of cane-sugar for monochromatic light, which, for most purposes may be placed at 66·4°. When the sp. gr. of the solution operated upon is known, the percentage by weight can be calculated by dividing the value of C obtained as above by the density.

Analysis of Commercial Glucose or Starch-sugar.—The production of this sugar has already been described (see pp. 1914–21). It occurs either as solid and granular powder, or a syrup of the character of honey. As in the case of cane-sugar, the full or complete analysis is attended with considerable difficulty, and it is therefore customary to return only 4 or 5 leading figures, which in most cases are sufficient for commercial purposes. The different processes will first be dealt with separately, and then the way in which they are carried out, and the mode in which the results are returned.

The sp. gr. of dextrose solution differs somewhat from that of cane-sugar containing the same amount of solid matter; Pohl gives the following table :—

Density of Solution.	Per cent. Sugar.	Difference in Density.
1·0072	2	− 8
1·0200	5	− 1
1·0275	7	− 6
1·0406	10	+ 1
1·0480	12	− 7
1·0616	15	+ 0
1·0693	17	− 11
1·0831	20	− 7
1·0909	22	− 20
1·1021	25	− 47

Determination of Dextrose by means of Fermentation.—A standard solution of the sample to be examined is made, and the percentage of dry matter estimated. A weighed quantity of yeast is then added to the solution, and it is submitted to fermentation; after the alcohol and carbonic acid formed have been expelled, the percentage of dry matter is again determined by the difference in weight of the entire apparatus before and after fermentation. The difference between the amounts of dry matter before and after the fermentation shows the amount of sugars in the fermentable form. The process incurs a certain loss, which may and frequently does amount to 5 per cent. of the total fermentable sugars present, because part of these in the course of the vinous fermentation are converted into glycerine, succinic acid, and other bodies, which are fixed at the temperature of boiling water, and consequently remain with the residue.

For instance, 100 *grm.* of glucose or starch-sugar, after dissolving in water, and diluted to 1 *litre*, would have a sp. gr. of about 1·030, and it appears from the table above that this corresponds to a percentage of the dried substance of 7·463; but as the substance has been weighed instead of being measured in *cc.*'s, the true percentage as contained in the solution will be 76·87 per cent. dry substance, and 23·13 per cent. water; ½ *litre* of the solution thus made is taken, and a sufficient quantity of fresh yeast, which is active and in good condition, is added; the whole is then placed in a fermenting apparatus, so that the carbonic acid can escape after drying. After weighing the whole apparatus, it is placed on one side at a proper temperature for about 3 days, weighing at intervals in order to ascertain when the action is complete. The liquid in the flask to which the yeast has been added is then measured, and boiled in order to drive off any residual alcohol, and, after cooling, is made up to its original volume, and returned to the flask. The amount of fermentable sugars is ascertained by the difference between the weight of the entire apparatus before and after fermentation. Thus if 500 *cc.* contained originally dry substance equal to 76·87 per cent. of total matter, and the liquid after fermentation contains the equivalent of only 20·67 of unfermentable matters, the residue of fermentable sugars will be 56·20; adding to this 5 per cent. on the quantity found, say 28·04 per cent., gives 58·24 per cent. as the total amount of fermentable sugars probably present.

The main difficulty in this process is the time which it takes, and the fact that from possible non-activity of the yeast it is essential to make 2 analyses of each sample with yeast obtained from different sources.

The proportions of maltose, dextrine, and glucose in brewing sugars prepared from starch may be determined by the optical method in conjunction with Fehling's test. It is necessary first to determine the specific rotatory power of the sample, which is done by dissolving a known weight of the substance in water, and making up to a certain volume; the solid matter is determined from the sp. gr. of the solution, by dividing by 3·85. This figure is constant, and allows an increase of 3·86 in density for each 1 *grm.* of sugar or other carbohydrate in 100 *cc.* of the liquid. The following example is given by A. H. Allen :—

(*a*) On ignition the sample left 0·63 per cent. of ash.

(*b*) The sp. gr. of a solution of 20 *grm.* of the sample diluted to 100 *cc.* was 1063·32 at 15½° (60° F.). This figure divided by 3·85 gives:—

Total solids	82·23 per cent.
Less ash	0·63 ,, ,,
Carbohydrates	81·60 ,, ,,

(*c*) By Fehling's test, the sample was found to have a reducing power equivalent to 72·6 per cent. of glucose. The reducing power of maltose may be taken as $\frac{62}{100}$ that of glucose.

(*d*) A solution of 20 *grm.* per 100 *cc.* observed in a 2-*decim.* tube caused an angular rotation of + 23·7° for the sodium line D. Hence the value of [*a*] D for the sample was + 59·25°, thus—

$$[\alpha]_D = \frac{23\cdot 7}{2 \times \frac{20}{100}} = 59\cdot 25.$$

The values of $[\alpha]_D$ for dextro-glucose, maltose, and dextrine are respectively + 52°, + 139°, and + 193°, ignoring fractional parts of a degree.

Let $[\alpha]_D$ be the apparent specific rotatory power, K the cupric oxide reducing power of the sample, and *g*, *m*, and *d* the respective amounts of glucose, maltose, and dextrine contained in 1 *grm.* of the sample. Then from the above data the following equations result:—

1. $g + m + d = \cdot 816.$
2. $g + \cdot 62\, m + = K = \cdot 726.$
3. $52\, g + 139\, m + 193\, d = [\alpha]_D = 59\ 25.$

From these

$$g = \cdot 726 - \cdot 62\, m.$$

$$d + g = \cdot 816 - m.$$
$$d + \cdot 726 - \cdot 62\, m = \cdot 816 - m.$$
$$\text{and } d = \cdot 09 - \cdot 38\, m.$$

Substituting the above values for *g* and *d* in equation 3, we get

$$52\,(\cdot 726 - \cdot 62\, m) + 139\, m + 193\,(\cdot 09 - \cdot 38\, m) = 59\cdot 25.$$

Simplying this,

$$37\cdot 752 - 32\cdot 24\, m + 139\, m + 17\cdot 37 - 73\cdot 34\, m = 59\cdot 25.$$

Simplifying again, and transposing, we get

$$33\cdot 42\, m = 4\cdot 128,$$

whence $m = \cdot 1235.$

The value of *m* being found, those of *g* and *d* are easily derived from equations 1 and 2. Thus:—

$$g = \cdot 726 - \cdot 62\,(\cdot 1235) = \cdot 726 - \cdot 07657 = \cdot 64943.$$
$$d = \cdot 816 - m - g = \cdot 816 - \cdot 1235 - \cdot 6494 = \cdot 0431.$$

As these values represent the respective weights of glucose, maltose, and dextrine in 1 *grm.* of the sample, the percentages will be 64·94, 12·35, and 4·31, together making up 81·60 per cent.

Determination of Sugar by Fehling solution.—This process alone is incorrect as applied to brewing sugars, because maltose, which is almost invariably present in large quantity, acts upon oxide of copper in a different proportion to that in which true grape-sugar acts; thus, while 100 parts of dextrose throw down 220 parts of suboxide of copper, 100 parts of maltose only reduce 141 parts of suboxide of copper. This test, therefore, is only of relative value.

Rumpf and Heinzerling state that solutions of (1) caustic soda and cupric sulphate at the boiling-point do not act on dextrine entirely free from sugar, which corrects Gerhardt's observation, who asserted that dextrine caused a reduction; (2) solutions of alkaline tartrates and Fehling's solution each act upon dextrine, making the results of the dextrose estimation too high in direct proportion to the length of time the heating is continued. When the reduction is quickly effected, and the heating continues only a few minutes, they have found that the error in the estimation of dextrose in the presence of dextrine in starch-sugars is too small to sensibly affect the results.

Anthon's method depends on the fact that the impurities present in commercial starch-sugar have a greater density than the sugar. The process is somewhat empirical, but is said to give fairly accurate results. A saturated solution of starch-sugar is made by dissolving an excess of sugar in a finely divided state in water. The sp. gr. of the clear solution thus produced is ascertained, and from this the percentage of impurity is calculated according to the following table:—

Density of sat. solution.	Per ct. of impurities.	Density of sat. solution.	Per ct. of impurities.	Density of sat. solution.	Per ct. of impurities.
1·2060	0	1·2350	15	1·2587	30
1·2082	1	1·2368	16	1·2603	31
1·2104	2	1·2386	17	1·2618	32
1·2125	3	1·2404	18	1·2633	33
1·2147	4	1·2422	19	1·2649	34
1·2169	5	1·2440	20	1·2665	35
1·2189	6	1·2456	21	1·2680	36
1·2208	7	1·2473	22	1·2695	37
1·2228	8	1·2489	23	1·2710	38
1·2247	9	1·2506	24	1·2725	39
1·2267	10	1·2522	25	1·2740	40
1·2284	11	1·2535	26	1·2755	41
1·2300	12	1·2548	27	1·2770	42
1·2317	13	1·2561	28	1·2785	43
1·2333	14	1·2574	29		

Water.—This is determined by drying the sample when admixed with dry and well-washed sand, as described under the analysis of molasses (see p. 1946). When solid samples of glucose have to be examined for moisture, the solid matter is first melted in a weighed dish in the water-bath at a gentle heat, and a weighed quantity of sand is stirred in.

Admixture of Starch-sugar with Cane-sugar.—It is stated that raw sugars are sometimes adulterated with starch-sugar, and the following methods have been suggested for the detection of the adulteration. It does not appear that the admixture has ever been common in this country, but in America it is said to be very frequent, and it is quite possible that it may prove profitable, because not only is the price of dextrine far lower than that of raw sugar, but it is somewhat similar in colour, and also shows far higher polariscopic reading, 0·40 per cent. of dextrine corresponding to 1 per cent. of sugar.

If the suspected sugar is mixed with water and absolute alcohol, or with alcohol of 95 per cent., and the sugar is washed with it on the filter, there will in most cases be a white coagulum of dextrine left behind, which is recognized by its appearance. If cane-sugar has been adulterated with starch-sugar, the sample on solution in water generally leaves some particles of glucose, which do not dissolve easily or readily. They are mostly white in colour, and if they are sufficient in quantity, it will be found that, on dissolving them in a larger quantity of water and submitting them to the polariscopic test, the reading is markedly different to that of cane-sugar, and not only so, but it gradually diminishes for some hours after the solution has been made. As the rotatory power of starch-sugar is in excess of that of cane-sugar, samples which are adulterated with any notable proportion of starch-sugar will generally give a reading in excess of that which is due to the cane-sugar present, and in consequence the figures of the analysis will very frequently add up to more than 100 per cent.

Casamajor has recommended the use of methylic alcohol of 50 per cent. strength saturated with starch-sugar, as a solution for the purpose of detecting the admixture of starch-sugar with cane-sugar. The mode of applying this test is to wash the suspected sugar with the saturated solution of starch-sugar in methylic alcohol, which readily dissolves the cane-sugar and other impurities, leaving the starch-sugar insoluble; this method, though of value as a qualitative test, cannot be recommended for quantative work.

Chandler and Ricketts' method is probably the best which has yet been proposed for the detection of starch-sugar in cane-sugar, but it is not readily applicable, and is attended with some degree of difficulty in execution. It depends upon the fact that the rotation of a solution of levulose varies with the temperature, while the rotation of dextrose is constant for all temperatures. As invert sugar consists of a mixture of dextrose and levulose in equal proportions, it follows that there is a certain temperature at which invert sugar has no effect upon the polariscope. Hence if a sample of commercial sugar, whether raw or refined, is inverted and heated to a certain definite temperature, viz. 87·2° (189° F.), the rotation of the levulose is neutralized by the dextrose, and the sample does not produce any rotation. Hence if the tube containing the solution of the sample is placed between the polarizer and the analyzer, and surrounded by a jacket or water-bath in such a way that its temperature can be kept definite at 87·2° (189° F.), the rotatory effect due to the cane-sugar is eliminated, and the rotation which is found by the optical examination is due entirely to glucose or intermediate products present. It is obvious that this method requires a special apparatus, inasmuch as the water-bath must be kept uniformly at a fixed temperature; but it is a decided advantage in detecting the presence of the adulterant if its quantity is at all notable, though it is not of use for detecting the character of that adulterant without the use of additional processes.

Analysis of Animal Charcoal, Char, or Bone-black (see pp. 443–4).—Animal charcoal differs much in character, the difference being dependent partly upon the character of the bones used in making it, viz. whether they are fresh or stale, whether they have been thoroughly freed from membranous matters, and more especially whether they have been boiled so as to separate the fatty matters (see pp. 1448–50), or simply cleared from meat in the ordinary way practised by butchers. The greater part of the animal char used in this country is made here from bones obtained from dealers who buy up the residues from butchers and from house use.

Animal char has a remarkable decolorizing power, not only on sugar, but on other coloured solutions. This power has been known and in many cases used chemically for 60–70 years, but it appears to have been in 1821 that Bussy & Pan first thoroughly investigated its manufacture and modes of action. At first it was customary to use it in a fine powder, in which state it is doubtless more efficient; but after once using in this condition, its power is almost destroyed, and it is incapable of being revivified, whereas Dumont discovered in 1828 that by recalcining char which had been used in the form of grains, it was possible to use it repeatedly without any notable diminution in its decolorizing power.

The manufacture from bones is in this country practically in the hands of some 3 or 4 firms. There is nothing peculiar about the process. Certain volatile products pass over from the retorts, —bone-oil (see p. 1360) and animal pitch, both of which have certain limited commercial uses, and a considerable quantity of gas is given off, which is in one or two cases used to light the factories in which the process is carried on (see p. 1450). The general composition of an average sample of good char is similar to the following. Further on will be pointed out alterations in character which take place as the char is used and revivified.

Carbon	11·00	Sulphate of lime	0·20
Carbonate of lime	8·00	Oxide of iron	0·10
Phosphate of lime and magnesia	80·00	Silica	0·30
Alkaline salts	0·40		

It is probable that the action of charcoal in removing colour is entirely physical. Some soluble colouring matters are absolutely absorbed, but these in most cases are given up again to the washing-water, and are therefore simply removed from the refined sugar to the sugar of inferior grades.

The following analyses, taken from the working of a sugar-refinery, show the absorptive power of char for impurities found in sugar solutions:—

	Raw Liquor.	Filtered Liquor.	Char Washings.
Sugar	93·50	95·30	78·50
Grape-sugar	2·14	2·25	3·23
Organic matter not sugar	3·56	2·00*	11·05
Ash	0·80	0·45†	7·22
	100·00	100·00	100·00

* 43·82 per cent. absorbed. † 43·75 per cent. absorbed.

It is probable that the absorptive power of this bone-black is owing to the presence of carbon in a minutely divided state deposited upon what may be called a framework or skeleton of phosphate of calcium in an extremely porous condition, and hence the lighter the char the better it is likely to act.

The substances taken up by the char divide themselves naturally into 2 or 3 different groups; organic bodies of the albumen class are retained with such great tenacity that even after long washing with hot water they are not removed. Certain inorganic salts, such as carbonate of lime, are also obstinately retained, while other soluble substances which are taken up, such as gums and colouring matters, and inorganic bases combined with organic acids, comparatively readily wash out from it.

Walkhoff, many years ago, working with weak solutions of potash and soda salts, arrived at the following results as to the absorptive power of char on the salts mentioned:—

	Per cent. absorbed.		Per cent. absorbed.
Potassium hydrate, at 60° (140° F.)	13·5	Sodium carbonate	24·0
,, ,, at 15° (59° F.)	16·6	,, ,, at 60° (140° F.)	18·3
,, carbonate	25·0	,, phosphate	32·3
,, phosphate	30·7	,, ,,	28·0
,, nitrate	6·5	,, nitrate	5·0
,, chloride	3·0	,, sulphate	20·4
,, ,,	1·3	Magnesium sulphate	49·0
,, citrate	12·2	Sodium chloride	1·0
,, sulphate	22·4		

The character of animal char differs greatly; that of thoroughly good quality is of black colour, and is entirely free from the appearance of incipient fusion or glazing on the surface. If this glazing is visible, it indicates a very inferior quality in the sample. The charcoal should not contain any undue proportion of white or grey particles, which result from excessive burning or access of air during the process. It should be tolerably uniform in size, according to the sized grain at which it is bought, and hard enough to resist the necessary handling to which it must be subjected.

The process of revivifying (see pp. 1923–6), consists in washing the char with hot water, which removes the traces of sugar which are left, and occasionally, though not always, washing it with dilute acids, so as to remove any excess of carbonate of lime which may be present in it; and after this washing or washings, calcining it in a closed retort in a similar way to that in which it was first calcined. If the washing is not carried far enough, the ignition of the residual sugar produces an increased amount of carbon, and so injures the quality of the revivified char. The heat employed in the revivification must be sufficient to perfectly char any organic matter which is present; the consequence is that in this burning process an additional quantity of inert non-nitrogenous carbon is deposited in the body of the grain, which not only makes the char itself more dense, but decreases the amount of cellular particles, and diminishes its decolorizing power. It is generally possible to distinguish old char from new char by the proportion of carbon present. The following table (from Tucker) gives a series of analyses of char which had been used in a refinery for different periods:—

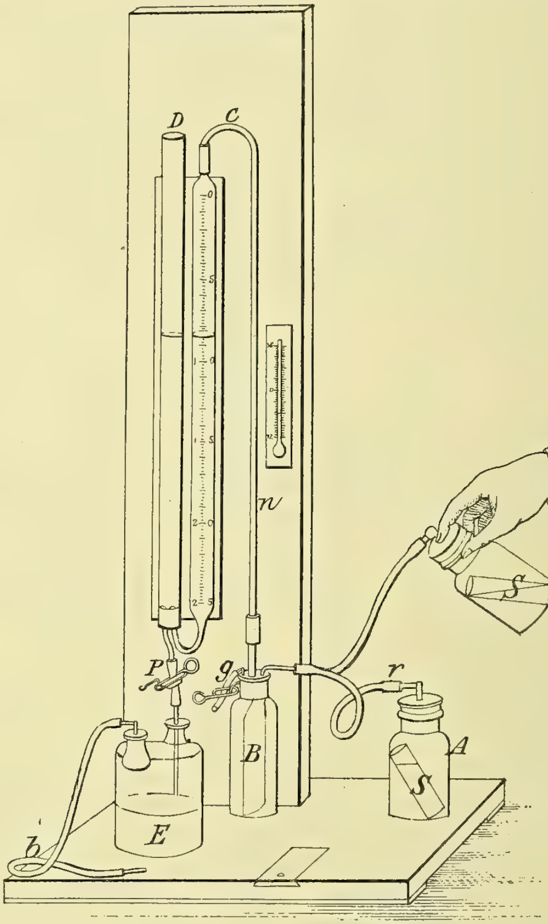
	Average of new black.	April 4.	May 1.	May 22.	June 3.	July 12.	Aug. 7.	Sept. 20.	Oct. 15.	Nov. 6.	Dec. 1.	Dec. 8.	Jan. 8, 1878.
Moisture	3·37	0·68	..	..	..	..	..	..	..	..	..	..	..
Carbon	8·05	7·65	8·05	8·38	8·74	9·62	9·15	9·44	9·59	9·89	10·07	10·07	10·01
Carbonate of lime	6·71	5·03	5·47	6·11	5·40	4·86	4·34	4·21	4·33	4·12	4·08	4·16	4·14
Iron	0·18	0·21	0·21	0·23	0·19	0·24	0·20	0·25	0·32	0·34	0·32	0·33	0·36
Insoluble matter	0·43	0·45	0·46	0·58	0·26	0·48	0·44	0·38	0·34	0·44	0·33	0·63	0·42
Sulphate of lime	..	..	0·35	..	..	0·49	0·34	0·44	..	0·49	0·31	..	..
Sulphide of calcium	..	..	..	..	..	..	..	..	..	..	..	..	0·41
Lb. per cub. ft.	42·70	49·90	51·30	52·90	52·90	53·90	51·90	56·40	55·50	55·30	58·80	61·70	58·70
Decolorizing power—per cent. of colour absorbed from a sugar solution	58·20	..	..	54·00	52·70	..	52·30	51·80	51·80	43·50	47·60	48·00	..

Nitrogen in a state of combination is present in almost all good char. It is difficult to understand why it should be so important in connection with the value of the char for purifying purposes; still it is seldom that char which contains a very small proportion of nitrogenous matter will be classed as efficient or useful for practical work.

Analysis of Animal Charcoal.—For determination of water, dry for 3–4 hours until the sample ceases to lose weight. For determination of carbon, weigh 4 or 5 *grm.* of the finely powdered char, transfer to a flask, and boil with about 70 *cc.* of dilute hydrochloric acid (1 of acid to 1 of water); dilute with hot distilled water, settle, and decant on to a tared filter; wash the sediment 2 or 3 times with very dilute acid, passing the washings through the same filter, and finally wash the carbon in the usual way on to the filter. After washing on the filter until the washings are no longer acid, dry the filter at 100° (212° F.), until it ceases to lose weight, and weigh; then transfer the filter to a weighed crucible, ignite, and reweigh. The loss of weight is the amount of carbon, plus the volatile matter and the filter itself; while the residue left in the crucible is the fixed ash of the filter, plus the insoluble ash of the char.

The determination of carbonate of lime is very frequently necessary in dealing with char; the instrument usually adopted for this in sugar-refineries is Scheibler's calcimeter. This apparatus is not very accurate, but the results are to be relied upon within 0·2–0·3 per cent., and therefore sufficiently near for ordinary work in refineries. The apparatus is shown in Fig. 1425, and consists of the following parts. The evolution-flask, in which the sample of char is treated with hydrochloric acid, is placed in the glass tube S. This flask is shown in two positions, one in the stand on the base-board, and the other when lifted in the hand during the process of analysis. The glass stopper of the flask A is perforated, and carries a tube to which is joined an indiarubber tube *r*, connecting the flask A with the bottle B. This bottle B has an indiarubber stopper with 3 holes, each fitted with a tube; the tube joined to *r* stands a short distance inside the vessel B, and the neck of it has fastened to it a thin indiarubber bag or bladder, similar to those commonly used for making toy balls. Tube *g* has a piece of indiarubber tubing connected with it, which is closed by a pinchcock while the estimation is being made, and serves to bring the vessel B into communication with the air when necessary. The glass tube *n* connects the interior of the vessel B with the top of the graduated tube C, which is divided into 25 equal parts (about 4 *cc.* each), each division being subdivided into tenths; the lower part of this is in communication with the straight tube D, which is open at the upper end, and closed at the lower end by an indiarubber cork pierced with two holes, through one of which is passed a pipe leading from the graduated tube C and through the other tube to the two-necked Wolff-bottle E, the action between the two being regulated by the pinchcock P. E is a reservoir for water, and C D are filled from it by blowing through the flexible tube *b*, the pinchcock P preventing the reflux of the water. The whole apparatus excepting the bottles is fastened to an upright board, and the bottles are supported when necessary on a shelf attached to the board.

1425.



The test of a sample of char is carried out in the following way. By blowing through the flexible tube *b*, the liquid is forced into the tubes C D until it reaches a little above the zero point in C, when it is allowed to fall by opening P until the level in C is at zero. The water must not be allowed to flow into B, as if this were done it would be necessary to take the apparatus to pieces to dry B. A sample of the char is pulverized, and the normal weight, viz. 1·702 *grm.* is placed in the flask A, carefully dried before use, and the small test-tube S, filled with dilute hydrochloric acid of sp. gr. 1·120, is cautiously placed in the flask, so that none of the acid shall be spilt. The stopper, which should be well greased, is now placed in A, and connection made with B by means of the tube *r*. If the levels of the liquids in D and C are unequal, the cock *g* must be opened for a few seconds to allow them to recover their normal level. The vessel A is now lifted from the shelf into the upper position shown, so that the acid may flow out of the tube and come into contact with the char; the flask being gently shaken causes the acid to mix thoroughly with the sample. The gas evolved escapes into the indiarubber bag contained in the flask B, which forces air up the capillary tube *n*, and depresses the column of water in the graduated tube C. The stopcock P is now cautiously opened, so as to let the water in the tube D flow out, keeping the levels of water in the two tubes as nearly as possible alike. When all the gas has been given off, and the level of the liquid in the tube C becomes stationary, the liquid in the two tubes is brought to the same level by opening the pinchcock P, and the volume and temperature are read off. The following table gives the percentage of carbonate of lime found corresponding to each division as read off on this instrument when the normal weight has been used, with the proper corrections for temperature (in degrees C.). The use of this determination in practical work is for the purpose of enabling a refiner to remove the carbonate of lime by washing with dilute acid. It may be assumed that 7 per cent. is the normal amount of carbonate of lime contained in animal char, and this table gives the quantities of commercial hydrochloric acid containing 33·3 of real acid necessary for the purpose of removing any excess of carbonate of lime which may be found.

TABLE FOR CALCULATING THE PERCENTAGE OF CARBONATE OF LIME FROM THE VOLUME OF CARBONIC ACID : FOR USE WITH SCHEIBLER'S CALCIMETER.

Volume read.	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
1	·80	·80	·79	·79	·79	·78	·78	·77	·77	·77	·76	·76	·76	·75	·75	·74	·74	·73	·73
2	1·88	1·87	1·86	1·86	1·85	1·84	1·83	1·82	1·81	1·80	1·79	1·79	1·78	1·77	1·76	1·75	1·74	1·73	1·72
3	2·95	2·94	2·92	2·91	2·90	2·89	2·87	2·86	2·85	2·83	2·82	2·80	2·79	2·77	2·76	2·74	2·73	2·72	2·71
4	4·01	4·00	3·98	3·96	3·94	3·93	3·91	3·89	3·87	3·85	3·83	3·81	3·79	3·77	3·75	3·73	3·71	3·70	3·68
5	5·07	5·05	5·03	5·00	4·98	4·96	4·93	4·91	4·87	4·86	4·84	4·81	4·79	4·76	4·74	4·71	4·69	4·67	4·65
6	6·11	6·09	6·06	6·03	6·01	5·98	5·95	5·92	5·89	5·86	5·83	5·81	5·78	5·75	5·71	5·68	5·65	5·63	5·61
7	7·14	7·12	7·09	7·06	7·02	6·99	6·96	6·92	6·89	6·86	6·82	6·79	6·75	6·72	6·68	6·65	6·61	6·58	6·56
8	8·17	8·14	8·11	8·07	8·03	8·00	7·96	7·92	7·88	7·84	7·80	7·76	7·72	7·68	7·64	7·59	7·55	7·53	7·49
9	9·19	9·16	9·12	9·07	9·03	8·99	8·95	8·90	8·86	8·82	8·77	8·73	8·68	8·64	8·59	8·55	8·50	8·46	8·42
10	10·20	10·16	10·12	10·07	10·02	9·98	9·93	9·88	9·83	9·79	9·73	9·68	9·63	9·58	9·53	9·48	9·43	9·39	9·34
11	11·20	11·15	11·10	11·05	11·00	10·95	10·89	10·84	10·79	10·74	10·68	10·63	10·57	10·52	10·46	10·41	10·35	10·30	10·25
12	12·20	12·15	12·09	12·03	11·98	11·92	11·87	11·81	11·75	11·69	11·64	11·58	11·52	11·46	11·40	11·33	11·27	11·22	11·16
13	13·20	13·14	13·08	13·02	12·96	12·90	12·84	12·78	12·72	12·65	12·59	12·53	12·46	12·40	12·33	12·26	12·20	12·14	12·07
14	14·20	14·14	14·07	14·01	13·94	13·88	13·81	13·75	13·68	13·61	13·54	13·48	13·41	13·34	13·26	13·19	13·12	13·05	12·99
15	15·20	15·13	15·06	14·99	14·92	14·85	14·78	14·71	14·64	14·57	14·50	14·42	14·35	14·27	14·20	14·12	14·04	13·97	13·90
16	16·20	16·13	16·05	15·98	15·91	15·83	15·76	15·68	15·61	15·53	15·45	15·37	15·29	15·21	15·13	15·05	14·97	14·89	14·81
17	17·20	17·12	17·04	16·97	16·89	16·81	16·73	16·66	16·59	16·49	16·41	16·32	16·24	16·15	16·07	15·98	15·89	15·81	15·72
18	18·20	18·12	18·03	17·95	17·87	17·79	17·70	17·62	17·53	17·45	17·36	17·27	17·18	17·09	17·00	16·91	16·82	16·73	16·63
19	19·20	19·11	19·03	18·94	18·85	18·76	18·67	18·59	18·50	18·40	18·31	18·22	18·13	18·03	17·94	17·84	17·74	17·64	17·55
20	20·20	20·11	20·02	19·93	19·83	19·74	19·65	19·55	19·46	19·36	19·27	19·17	19·07	18·97	18·87	18·77	18·66	18·56	18·46
21	21·20	21·10	21·01	20·91	20·81	20·72	20·62	20·52	20·42	20·32	20·22	20·12	20·01	19·91	19·80	19·70	19·59	19·48	19·37
22	22·20	22·10	22·00	21·90	21·80	21·70	21·59	21·49	21·39	21·28	21·17	21·07	20·96	20·85	20·74	20·63	20·51	20·40	20·28
23	23·20	23·09	22·99	22·88	22·78	22·67	22·56	22·46	22·35	22·24	22·13	22·02	21·90	21·79	21·67	21·55	21·44	21·31	21·20
24	24·20	24·09	23·98	23·87	23·76	23·65	23·54	23·43	23·31	23·20	23·08	22·97	22·85	22·73	22·61	22·48	22·36	22·23	22·11
25	25·20	25·08	24·97	24·86	24·74	24·63	24·51	24·39	24·28	24·16	24·04	23·91	23·79	23·67	23·54	23·41	23·28	23·15	23·02

For determination of sulphate of lime, 10 *grm.* of the finely pulverized sample are placed in a porcelain basin with 80 *cc.* of dilute hydrochloric acid, and heated for 1 hour on the water-bath ; the residue is washed into a 250-*cc.* flask, diluted to the mark, and filtered ; 200 *cc.* of the clear filtrate, corresponding to 8 *grm.* of the original substance, are precipitated with chloride of barium, heated, and the precipitated barium sulphate is filtered off, the residue being washed on the filter with hot water slightly acidified with hydrochloric acid ; the filtrate is dried, precipitated, and ignited in the usual way, and the residue of sulphate of barium × ·582 = calcium sulphate. For determining calcium sulphide, 10 *grm.* of the powdered sample are weighed, transferred to a porcelain dish, and treated on the water-bath with 20 *cc.* of fuming nitric acid, which must be added cautiously, to prevent too violent effervescence. After ½ hour, 20 *cc.* more of fuming nitric acid and 20 *cc.* of pure hydrochloric acid are added, and the whole is stirred for 20 minutes longer. The mixture is now evaporated to dryness, and the contents of the dish are washed into a 250-*cc.* flask; the liquid when cooled is diluted to the mark, and filtered ; 200 *cc.* of the filtrate, corresponding to 8 *grm.* of char, are precipitated with barium chloride, and the amount of barium sulphate precipitate is determined as before ; the difference between the weight of the barium sulphate in the two cases corresponds to the amount of calcic sulphide present, and may be calculated thus,—barium sulphide × ·309 = calcic sulphide.

Calcic phosphate may be estimated by cautious ignition of about 1 *grm.* of the finely powdered char, dissolving the residue in dilute nitric acid, and precipitating by magnesia solution, as in the ordinary determination of phosphates. Where accuracy is necessary, the precipitate should be redissolved after washing with water in dilute hydrochloric acid, and reprecipitating with ammonia.

Determination of iron is seldom necessary, and a qualitative test is generally sufficient, the reactions obtained in this way being enough to show whether iron is present in sufficient quantity. The soluble matters are determined by boiling a quantity (preferably not less than 50 *grm.*) of the roughly powdered char with water, decanting, boiling again, making up the liquid to a known volume, and evaporating half of it. The weight of the dried residue is the total soluble matter, and this, if cautiously ignited at a low red heat, leaves the soluble mineral matter, which can then be weighed. The difference is the organic soluble matter. In the other half of this solution, the sugar and glucose should be determined by means of Fehling solution.

Two specific-gravity determinations are required in this case, one of the apparent sp. gr., and the other of actual sp. gr. The first is obtained by filling a flask of known capacity (say ½ *litre*) with the sample of char, shaking it gently so as to ensure its being properly packed, and filling up to the mark. The weight of the contents, after deducting the tare of the flask, as compared with the weight of the same flask in distilled water, gives the apparent sp. gr. of the char. The actual or real sp. gr. is obtained by weighing 100 *grm.* of the char in a tared 200-*cc.* flask, partially filling it with distilled water, boiling for some minutes to free the char from air, then cooling, filling up to the mark, and weighing. The amount of water displaced by the char is obtained by comparison with the actual contents of the flask, and gives the real sp. gr. of the char.

The decolorizing power of char on sugar is determined by taking solutions of dark coloured sugar, and diluting them until the tint is such that they are capable of being estimated in one of the numerous forms of colorimeters now in use. Duboscq's colorimeter, which is perhaps most generally used, consists of two glass cylinders side by side, one of which is destined to receive the solution to be examined, and the other the standard liquor. Two small tubes capable of being moved up and down through the corks which close the tops of the larger tubes are shut at the bottom by clear glass plates, and passed through the corks. Below the larger tubes, is a mirror to reflect the light in a vertical direction through them, and above them are two double-reflecting prisms, which bring the images of the two smaller tubes side by side into the luminous field of a small Galilean telescope. In this case, the samples are worked against a standard solution made by dissolving caramel in water. Practically the test is best made by shaking a weighed quantity of the charcoal to be tested and a sugar solution of known quality, and comparing with another standard sample of charcoal weighed in equal proportions to the same sugar solution, then examining the relative decolorizing powers by any of the known colorimeters.

Milk-sugar, Characters and Analysis.—Milk-sugar, lactose, or lactine ($C_{12}H_{22}O_{11}$), an isomer of cane-sugar, is prepared from milk, which contains about 4 per cent., in the manner described on pp. 1903–4; the product thus obtained can be further purified by passing its aqueous solution through animal charcoal, evaporating the water, and recrystallizing. Milk-sugar crystallizes in hemihedral trimetric prisms, of the composition $C_{12}H_{22}O_{11}+H_2O$; by heating to 130° (266° F.), the crystals melt and lose one atom of water; the anhydrous milk-sugar, which remains in the form of a liquid mass, solidifies into small crystals on cooling. Milk-sugar dissolves readily in weak acetic acid, and crystallizes again unaltered; it is insoluble in absolute alcohol and ether, soluble in 5–6 parts of cold and 2½ parts of boiling water. A saturated solution in water has a density of 1·055, and contains 14·55 per cent. crystallized milk-sugar; when concentrated, this solution deposits crystals so soon as it has attained a density of 1·062; it then contains 21·64 per cent. milk-sugar. This change in solubility is accounted for by Hesse on the supposition that the size of the molecules of the two modifications of milk-sugar stand to one another as 3 to 2, so that by boiling, the β variety is produced, the molecules of which occupy $\frac{1}{3}$ less space. The specific rotatory power for the α variety is $[\alpha]_D + 80°$, and for β variety 52·7°. Milk-sugar is charred by warm concentrated sulphuric acid; heated with the diluted acid, its optical rotatory power is increased, galactose ($C_6H_{12}O_6$) being formed; according to more recent researches, two sugars are formed (corresponding with dextrose and lævulose from cane-sugar), both fermentable, but differing in their solubility in alcohol, and in their specific rotatory power, though both are dextrorotatory. The specific rotatory powers for the two are given as—

$[\alpha]_D$ .. .. 92·83° | $[\alpha]_D$ .. .. 62·63°

Both are birotatory.

Milk-sugar ferments with yeast, but more slowly than grape-sugar or dextrose, yielding alcohol and carbonic acid; with most of the bases, it forms well defined compounds; it does not combine with sodium chloride. There are two calcium compounds of it, one soluble and containing equal numbers of molecules of lime and sugar, the other insoluble and containing a larger proportion of lime.

To determine the amount of milk-sugar present in milk, it is necessary first to remove the fat and caseine: the former obscures the liquid to such an extent that it is not possible to obtain accurate readings if the determination is made by polariscope, nor accurate results if by means of Fehling solution; and the caseine has a considerable left-handed rotation. Owing to the birotation which is exhibited by milk-sugar, it is undesirable to employ the optical method if it can be avoided, and the Fehling process is the more reliable of the two.

The mode in which the estimation is carried out is similar to that used for glucose and invert sugar (see p. 1963), except that the solutions have to be heated or boiled somewhat longer, as the action does not take place so rapidly, though the volumetric or gravimetric methods may be used.

It is preferable to employ a dilute solution of milk-sugar, say 0·1 per cent.; to a measured quantity while boiling, is added excess of boiling Fehling solution; the mixture is boiled for a few minutes, and the precipitate is allowed to settle, filtered, and treated as described on p. 1945: 1 equivalent of milk-sugar reduces 7 of cupric oxide.

Composition of Commercial Sugars.—The following are analyses of characteristic raw and refined commercial sugars made in 1881, by Wigner and Harland for the Food Collection at Bethnal Green Museum:—

Raw Sugars.	No.	Crystallizable Sugar.	Uncrystallizable Sugar.	Ash.	Moisture.	Unknown Organic Matters.
Dominica	5930	88·30	3·36	1·22	4·95	2·17
Grenada	5931	87·00	3·61	·90	4·74	3·75
Guatemala	5932	82·40	5·48	·78	6·30	5·04
Havana	5933	91·90	2·98	·72	1·70	2·70
Jamaica	5936	90·40	3·47	·36	4·22	1·55
Porto Rico	5940	87·50	4·84	·81	4·25	2·60
St. Kitts	5941	88·70	4·18	1·02	2·79	3·21
St. Lucia	5942	84·20	5·38	1·32	2·39	6·71
St. Vincent	5943	92·50	3·61	·63	·81	2·45
Surinam	5947	86·80	4·31	2·28	5·27	1·34
Trinidad	5948	88·00	5·14	·96	4·23	1·67
Grainy Peruvian	5949	94·80	1·44	·60	1·02	2·14
Cheney	5951	87·40	3·18	1·33	2·74	5·35
China	5952	72·50	9·19	1·80	6·76	9·75
Benares	5957	94·50	2·6	1·50	·98	·39
E. I. Date	5960	86·00	2·19	2·88	6·04	2·89
White Java	5961	99·20	·20	·20	·40	trace
Unclayed Manilla	5962	82·00	6·79	2·00	5·97	3·24
Refined Sugars—						
Tate's crystals	5973	99·90	none	trace	trace	none
French pulverized	5983	99·70	trace	·10	·20	,,
Martineau	5984	99·70	,,	·10	·20	,,
Duncan's granulated	5985	99·80	,,	·10	·10	,,
Say's loaves	5987	99·80	,,	·10	·10	,,
Martineau's tablets	5988	99·80	none	·10	·10	,,
Boyd titlers	5989	99·70	trace	·10	·20	,,
Beet-sugar loaf	6074	99·60	,,	·15	·25	,,
,, crystals	6076	99·90	none	trace	trace	,,

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PRODUCTION AND COMMERCE.—*Abyssinia.*—Our imports thence of unrefined sugar were 1880 cwt., 2430*l.*, in 1877.

Argentine Republic.—The provinces of Tucuman and Santiago, in the central part of the Republic, have lately imported much English machinery for sugar-making. The annual crop has a value of about 150,000*l.*

Australia.—The area occupied by sugar-cane in 1879 was 17,652 acres in Queensland, and 7778 in New South Wales. S. Australia is also entering on the culture. Queensland exported 5500 tons of sugar in 1880, the total crop amounting to over 20,000 tons. We imported 4525 cwt. of molasses, value 1628*l.*, from New South Wales in 1880.

Austro-Hungary.—The beet-crop in 1880 was 32,968,757 met. centners (of 110¼ lb.). The exports were:—Refined sugar: 675,000 met. cent.; raw: 1,624,000 met. cent.

Belgium.—Our imports therefrom of refined and candy were 35,775 cwt., 62,739*l.*, in 1877; 108,313 cwt., 155,340*l.*, in 1880. Unrefined: 578,931 cwt., 621,945*l.*, in 1876; 493,349 cwt., 540,241*l.*, in 1880.

Borneo.—In 1863, 200 acres were planted with cane; and in 1865, 10,000 dol. worth of sugar was exported.

Bourbon.—Cane acreage, 43,672 *hectares* (of 2½ acres) in 1874; exports to France in same year, 8,876,298 *kilo.* We imported thence 14,750 cwt. unrefined sugar, 16,880*l.*, in 1877.

Brazil.—The sugar-cane grows throughout Brazil, but chiefly in the provinces of Rio Janeiro, Sao Paulo, Bahia, Pernambuco, Parahiba, Ceará, Alagoas, and Rio Grande del Norte. Central factories are being widely established. The exports were:—From Maceio, in 1880, 366,443 bags (of 170 lb.), chiefly to the Channel and New York. Aracaju: 32,608,750 *kilo.* (of 2·2 lb.) in 1877, 19,422,075 in 1878, 15,871,240 in 1879; in the last year, 3,162,792 *kilo.* were white sugar, value 64,076*l.*, and 12,708,450 *kilo.* brown, value 177,968*l.* Pernambuco: 1626 tons, 17,670*l.*, in 1871; 10,278 tons, 117,860*l.*, in 1877; 9920 tons, 106,610*l.*, in 1880. Ceará: 48,846 bags in 1876, 560 in 1878. Total Brazilian exports: 206,682,123 *kilo.* in 1874–5; 146,857,810 in 1878–9. Our imports from Brazil were:—Unrefined: 1,860,707 cwt., 1,692,088*l.*, in 1879; 1,484,924 cwt., 1,512,709*l.*, in 1880.

Canada.—Both beet and sorghum growing are commencing to attract attention in Canada, where the climate is found to be well adapted to sugar raising. As yet there are no exports.

Cape Colony.—Our imports thence of unrefined sugar were 13,513 cwt., 13,352*l.*, in 1876; 45,277 cwt., 47,486*l.*, in 1880.

Cayenne.—The cane acreage in 1874 was 235 *hectares* (of 2½ acres). The annual production has fallen to about 250,000 *kilo.* (of 2·2 lb.).

Central America.—Our imports thence of unrefined sugar were 15,552 cwt., 18,228*l.*, in 1877; 1738 cwt., 1737*l.*, in 1880.

Chili.—Our imports thence of unrefined sugar were 29,590 cwt., 29,672*l.*, in 1876; 79,658 cwt., 90,766*l.*, in 1880.

China.—The total annual production is estimated at 200,000 tons, mainly from cane. There are two refineries in Hong Kong, and a third at Swatow, drawing supplies from China, Cochin China, the Philippines, Straits Settlements, and Java. Our imports of unrefined sugar from China, including Hong Kong and Macao, were 1,115,758 cwt., 1,150,653*l.*, in 1877; 359,821 cwt., 301,307*l.*, in 1880.

Colombia.—The sugar-cane is grown in Carthagena province to a limited extent. Our imports thence were:—Unrefined: 31,772 cwt., 31,567*l.*, in 1876; 17,919 cwt., 20,277*l.*, in 1880.

Danish W. Indies.—Our imports of raw sugar thence were 3 cwt., 3*l.*, in 1876, and 52,113 cwt., 63,859*l.*, in 1880.

Egypt.—Nearly 100,000 acres are under cane. The values of the exports in 1880 were:—320,554*l.* to Great Britain, 284,273*l.* France, 123,542*l.* Italy, 35,465*l.* Turkey, 700*l.* Greece, 22*l.* Austria, 11,196*l.* other countries; total, 775,752*l.* Our imports thence were:—Refined and candy: 8840 cwt., 11,340*l.*, in 1876; 59,474 cwt., 78,465*l.*, in 1880; unrefined: 220,459 cwt., 204,220*l.*, in 1876; 195,217 cwt., 229,381*l.*, in 1880; molasses: 1212 cwt., 360*l.*, in 1879; 30,057 cwt., 9408*l.*, in 1880.

France.—The annual production of beet-sugar is about 400 million *kilo.* (of 2·2 lb.), requiring 8 million tons of beet. The imports of sugar are about 180 million *kilo.*; the local consumption, 270 million. In 1875–6, 525 factories made 449 million *kilo.*; in 1879–80, 509 made 278 million; in 1880–1, the make was 320 million. The exports were:—From Calais: raw French, 298,922 *kilo.* in 1879, 11,614 in 1880; refined, not French, 24 in 1879, 108,709 in 1880; Dunkirk: sugar, 15,689,947 *kilo.* in 1879, 15,014,370 in 1880; glucose: 2,722,048 in 1879, 70,473 in 1880; all to England; Nantes: in 1880, 8,402,800 *kilo.* refined sugar, to England, Spain, Turkey, Chili, and Switzerland; and 236,274 *kilo.* treacle to Norway. Our imports from France were: Refined and candy: 2,313,676 *kilo.*, 3,391,378*l.*, in 1878; 1,586,416 *kilo.*, 2,342,912*l.*, in 1880; unrefined: 698,201 *kilo.*, 707,929*l.*, in 1876; 115,298 *kilo.*, 136,089*l.*, in 1880.

Germany.—The 1879–80 beet crop gave the following result:—Factories working, 328: 291 by diffusion, 28 by presses, 8 by maceration, 1 by centrifugal; beet used, 4,628,748 tons; yield of washed and topped roots, 25·2 *kilo.* (of 2·2 lb.) per *hectare* (of 2½ acres); yield of *masse-cuite*, 11·54 per cent.; yield from 100 *kilo.* of *masse-cuite*, 73·85 *kilo.* sugar, and 23·70 molasses; 100 *kilo.* of sugar required 1174 *kilo.* of roots. Our imports from Germany were:—Refined and candy: 30,976 cwt., 48,562*l.*, in 1876; 244,645 cwt., 339,969*l.*, in 1880; unrefined: 1,516,233 cwt., 1,688,786*l.*, in 1876; 4,384,268 cwt., 4,728,916*l.*, in 1880. The receipts of raw sugar at Hamburg were:—

Whence received.	1876.	1877.	1878.	1879.	1880.
	cwt.	cwt.	cwt.	cwt.	cwt.
Interior of Germany ..	1,500,597	1,548,745	1,977,488	2,467,966	4,379,716
Brazil	7*	22,181	566	19,237	Seawards 127,946
Porto Rico	5*	15,881	15,778	5,111	
Great Britain	12,146	16,928	7,078	9,649	
Cuba	4,822	..*	..*	..*	
Holland (by sea)	12,320	29,666	9,739	3,185	
Dutch East Indies ..	23,584	67,436	32,042	53,902	
Other countries	14,500	9,878	3,042	4,412	
Total	1,567,981	1,710,715	2,045,733	2,563,462	4,507,662

* In these years a total failure of the crop occurred.

Guatemala.—The exports of good sugar in 1879 were:—52,500 quintals (of 110 lb.) to England, 68,550 to California, 10,000 to S. America, 3000 to Central American States. Of common sugar, in the same year:—49,650 to England, 38,100 to New York, 53,700 to California, 19,900 to Central American States. Totals, 134,050 quintals, 13,405 dol. (of 4*s.* 2*d.*); and 161,350 quintals, 5647 dol. Escuintla is the centre of the principal sugar-growing district.

Guiana.—The cane acreage in May 1881 was 40,877 acres in Demerara, 18,286 in Essequibo, 15,294 in Berbice. The exports in 1880 were:—From Demerara, 69,682 hhds., 8228 tierces, 2321 bar. sugar; 16,976 casks molasses. Berbice: 1247 hhds., 37 tierces, 381 bar., 34,895 bags sugar; 25 puns. molasses. Our imports thence were:—Refined: 11 cwt., 19*l.*, in 1877; 16,338 cwt., 22,851*l.*, in 1880; unrefined: 1,569,893 cwt., 1,920,769*l.*, in 1876; 1,327,084 cwt., 1,778,481*l.*, in 1880; molasses: 2034 cwt., 765*l.*, in 1876; 20,888 cwt., 10,189*l.*, in 1880.

Holland.—Five years' commerce in raw and refined sugars, in Netherlands lb. (of 2·2 lb.), was:—

	1875.	1876.	1877.	1878.	1879.
	N. lb.	N. lb.	N. lb.	N. lb.	N. lb.
Imports, raw	62,700,000	69,900,000	58,500,000	59,000,000	43,000,000
Exports „	17,556,000	29,000,000	16,000,000	18,800,000	21,300,000
„ refined	76,778,400	74,800,000	62,500,000	64,400,000	63,800,000

Of 45,852,681 N. lb. of refined exported from Amsterdam in 1879, 32,639,733 N. lb. came to England. Our total imports from Holland of refined and candy were 647,605 cwt., 929,985*l.*, in 1876; 876,471 cwt., 1,275,717*l.*, in 1880. Unrefined: 298,440 cwt., 316,705*l.*, in 1876; 205,601 cwt., 223,900*l.*, in 1880.

Honduras.—Cane-sugar is easily produced here at 10*l.* a ton, and the rate of 2 tons per acre. Canes ratoon well for 10–12 and even 20 years. The area under cane is over 10,000 acres. The exports were 177½ tons in 1862, 2203 in 1872. Our imports thence of unrefined were 36,656 cwt., 32,078*l.*, in 1876; 18,207 cwt., 18,273*l.*, in 1880.

India.—The area under sugar-cane in British India is over 1½ million acres, chiefly in the N.-W. Provinces. The exports were 1,144,467 cwt., 999,503*l.*, in 1877; 368,566 cwt., 350,425*l.*, in 1879. Our imports of unrefined sugar were:—Madras: 150,484 cwt., 112,411*l.*, in 1879; 487,048 cwt., 349,803*l.*, in 1880. Bengal and Burma: 558,139 cwt., 646,844*l.*, in 1877; 25,851 cwt., 27,113*l.*, in 1880.

Java.—Cane acreage, about 70,000 acres. Crop of 1879, 3,933,000 *piculs* (of 135½ lb.); 1880, 3,294,500. Exports of 1879 crop:—2,356.530 *piculs* to Channel for orders, 329,053 Holland, 328,967 Australia, 284,458 America, 161,971 France, 35,975 Persian Gulf, 35,125 Singapore, 19,088 Lisbon for orders, 12,133 China, 10,403 Cadiz for orders, 2164 Siam; total, 3,575,867. Our imports from Java were:—Unrefined: 1,215,800 cwt., 1,400,981*l.*, in 1876; 1,763,522 cwt., 2,226,225*l.*, in 1880.

Mauritius.—In 1876, the export of home-made sugar was 115,801 tons; in 1877, 136,292; in 1878, 128,329. Our imports thence of unrefined sugar were 1,205,354 cwt., 1,747,147*l.*, in 1877; 120,516 cwt., 137,021*l.*, in 1880.

Mexico.—Our imports thence of unrefined sugar were 30,560 cwt., 32,532*l.*, in 1876; 94,879 cwt., 98,113*l.*, in 1880.

Natal.—The 1881 crop was estimated to produce 15,000 tons of sugar. Plant canes give 2½ tons sugar per acre, and 1st and 2nd ratoons, 1½ tons, on the average. Our imports thence of unrefined sugar were 22,189 cwt., 22,027*l.*, in 1876; 31,405 cwt., 29,234*l.*, in 1880.

New Zealand.—Beet has been grown in the Waikato district yielding 15 per cent. of sugar, and a German company are erecting a factory to make 10,000 tons of sugar per annum.

Pacific Islands.—The Sandwich Islands produce yearly about 30 million lb. of sugar, and 500,000 gal. molasses. Fiji had 1838 acres under cane in 1879. Tahiti has about 300 acres under cane.

Peru.—Annual production, about 100,000 tons of cane-sugar. The crop is remarkably certain. The exports were 60,000 tons in 1875, over 70,000 in 1876. Our imports of unrefined sugar thence were 1,000,987 cwt., 1,128,062*l.*, in 1880.

Philippines.—The sugar-cane is grown in Negros, Panay, Cebu, Luzon, and nearly every part of the Archipelago; the best sugar is from Pampanga and La Laguna, the worst from Taal or Batangas. The 1880 exports were 1,581,188 *piculs* (of 139½ lb.) from Manilla, 1,004,394 from Yloilo, 321,574 from Cebu; total, 2,907,156 *piculs*, 2,620,000*l.* Our imports thence of unrefined sugar were 1,027,365 cwt., 894,006*l.*, in 1876; 1,175,140 cwt., 983,590*l.*, in 1880.

San Domingo.—Exports in 1880:—Sugar: 3138 tons to the United States, 134 W. Indies, 25 Great Britain; total, 3297; molasses: 172,440 gal. United States. The actual total exports were at least 5000 tons, and cane-culture is spreading.

Servia.—A Russian company is about to introduce the culture of beet and manufacture of sugar. The climate promises success.

Siam.—Nachonyhaisi and Petno are the chief sugar districts, but the cane is also grown at Paklat, Bangpasoi, Chantibon, and Petchabure, to a considerable extent. The exports were 101,307 *piculs* (of 133¾ lb.) in 1870. Our imports of unrefined were 20,107 cwt., 23,140*l.*, in 1877.

Spain.—The sugar-cane is cultivated in Spain on that portion of the Andalusian coast which lies between 36° and 37° N. lat. The area is very limited. Beet is about to be introduced.

Straits Settlements.—Our imports thence of unrefined sugar were 101,219 cwt., 83,762*l.*, in 1876; 195,527 cwt., 159,155*l.*, in 1880.

Surinam.—In 1879, the cane acreage was 4389 *hectares* (of 2½ acres); the crop yielded 11,023,130 *kilo.* (of 2·2 lb.) of sugar, and 2,501,928 *litres* (of 1¾ pint) of molasses; the exports were 11,633,892 *kilo.* of sugar, and 1,936,802 *litres* of molasses. Our imports thence of unrefined sugar were 81,232 cwt., 85,734*l.*, in 1876; 74,959 cwt., 86,069*l.*, in 1880; molasses: 642 cwt., 301*l.*, in 1876; 2307 cwt., 846*l.*, in 1880.

United Kingdom.—No sugar is at present produced in the United Kingdom, but beet-sugar was largely made at Lavenham, Suffolk, a few years since, and the industry will probably be revived at no distant future. For beet-culture in England, see pp. 1832–4, for sorghum-culture, p. 1914.

Starch-sugar and brewing compounds are largely manufactured in London; and extensive sugar-refineries exist in London, Bristol, Greenock, &c.

Our imports in 1880 were:—Refined and candy: from France, 1,586 416 cwt., 2,342,912*l.*; Holland, 876,471 cwt., 1,275,717*l.*; Germany, 244,645 cwt., 339,969*l.*; Belgium, 108,313 cwt., 155,340*l.*; United States, 103,396 cwt., 161,384*l.*; other countries, 116,833 cwt., 161,550*l.*; total, 3,036,074 cwt., 4,436,872*l.* Unrefined: Germany, 4,384,268 cwt., 4,728,916*l.*; British W. Indies, 2,578,971 cwt., 2,738,322*l.*; Java, 1,763,522 cwt., 2,226,225*l.*; Brazil, 1,484,924 cwt., 1,512,709*l.*; British Guiana, 1,327,084 cwt., 1,778,481*l.*; Philippines, 1,175,140 cwt., 983,590*l.*; Peru, 1,000,987 cwt., 1,128,062*l.*; Spanish W. Indies, 640,810 cwt., 770,673*l.*; Belgium, 493,349 cwt., 540,241*l.*; Madras, 487,048 cwt., 349,803*l.*; China, 359,821 cwt., 301,307*l.*; Holland, 205,601 cwt., 223,900*l.*; Straits Settlements, 195,527 cwt., 159,155*l.*; Egypt, 195,217 cwt., 229,381*l.*; Mauritius, 120,516 cwt., 137,021*l.*; France, 115,298 cwt., 136,089*l.*; Mexico, 94,879 cwt., 98,113*l.*; Chili, 79,658 cwt., 90,766*l.*; British S. Africa, 76,682 cwt., 76,720*l.*; Dutch Guiana, 74,959 cwt., 86,069*l.*; Danish W. Indies, 52,113 cwt., 63,859*l.*; Bengal and Burma, 25,851 cwt., 27,113*l.*; Honduras, 18,207 cwt., 18,273*l.*; New Granada, 17,919 cwt., 20,277*l.*; other countries, 33,262 cwt., 32,898*l.*; total, 17,001,613 cwt., 18,457,963*l.* Glucose, solid or liquid: Germany, 218,745 cwt., 213,166*l.*; United States, 100,467 cwt., 91,063*l.*; France, 70,151 cwt., 69,733*l.*; other countries, 16,397 cwt., 13,775*l.*; total, 405,760 cwt., 387,737*l.* Molasses: United States, 92,000 cwt., 39,685*l.*; British W. Indies, 42,476 cwt., 16,937*l.*; Egypt, 30,057 cwt., 9408*l.*; British Guiana, 20,888 cwt., 10,189*l.*; Germany, 3515 cwt., 1571*l.*; Mauritius, 3475 cwt., 1379*l.*; other countries, 19,130 cwt., 7082*l.*; total, 211,541 cwt., 86,251*l.*

Our exports in 1880 were:—Refined and Candy: Portugal, Azores, and Madeira, 28,031 cwt., 36,815*l.*; Malta and Gozo, 17,103 cwt., 23,338*l.*; Channel Islands, 15,411 cwt., 22,666*l.*; Australia, 13,039 cwt., 19,470*l.*; Argentine Republic, 8742 cwt., 12,972*l.*; Gibraltar, 7635 cwt., 10,663*l.*; Turkey, 5218 cwt., 7590*l.*; France, 3712 cwt., 4581*l.*; Roumania, 3426 cwt., 5108*l.*; British S. Africa, 3221 cwt., 5210*l.*; Norway, 2166 cwt., 3323*l.*; Persia, 2005 cwt., 2754*l.*; Morocco, 1456 cwt., 2130*l.*; China, 1157 cwt., 2703*l.*; Italy, 1149 cwt., 1540*l.*; other countries, 11,771 cwt., 16,924*l.*; total, 125,242 cwt., 177,787*l.* Unrefined Beet-sugar: Portugal, 12,132 cwt., 17,020*l.*; other countries, 2842 cwt., 3738*l.*; total, 14,974 cwt., 20,758*l.* Cane and other sorts: Denmark, 71,108 cwt., 82,703*l.*; Portugal and Azores, 60,977 cwt., 71,465*l.*; Sweden, 41,312 cwt., 53,371*l.*; United States, 38,960 cwt., 42,634*l.*; Belgium, 21,581 cwt., 24,705*l.*; Holland, 19,935 cwt., 22,558*l.*; Germany, 15,554 cwt., 17,947*l.*; Italy, 10,949 cwt., 14,916*l.*; France, 9200 cwt., 12,049*l.*; other countries, 9085 cwt., 11,337*l.*; total, 298,661 cwt., 353,685*l.* Glucose: Australia, 23,075 cwt., 21,800*l.*; other countries, 770 cwt., 807*l.*; total, 23,845 cwt., 22,607*l.* Molasses: British N. America, 13,457 cwt., 9165*l.*; Norway, 9938 cwt., 5015*l.*; other countries, 15,631 cwt., 9435*l.*; total, 39,026 cwt., 23,615*l.*

United States.—Cane-sugar is mainly produced, but also beet-, maple-, melon-, and sorghum-sugars, as well as very large quantities of starch-sugar. The home growth of cane-sugar in 1870 was 80 million lb., and of maple, 28 million. The New York imports of sugar in 1880 were:—Foreign direct, 555,553 tons; melado, 6239; Texas, 895; Louisiana, 5260; other coastwise, 5167; total, 573,114 tons. Of molasses:—Foreign direct, 10,393,585 gal.; Louisiana, 4,382,595; other coastwise, 73,580; total, 14,849,760 gal. Exports: Molasses, 2,626,947 dol. worth; sugar, 59,348,432 dol. worth. Our imports thence were:—Refined sugar: 439,914 cwt., 624,670*l.*, in 1879; 103,396 cwt., 161,384*l.*, in 1880; unrefined: 4623 cwt., 5056*l.*, in 1878; 14,796 cwt., 14,466*l.*, in 1880; molasses: 511,699 cwt., 186,219*l.*, in 1879; 92,000 cwt., 39,685*l.*, in 1880.

Venezuela.—The 1873 crop of cane-sugar was about 5,000,000 lb. The exports from Puerto Cabello in 1879 were 38,760 *kilo.* (of 2·2 lb.) to Holland.

W. Indies.—The areas under cane culture are as follows:—Jamaica, 47,565 acres; Barbados, 35,000 acres; Martinique, 19,314 *hectares* (of 2½ acres). Sugar production:—Barbados, 37,400 hhds.; Trinidad, 59,000; Grenada, 3800; St. Vincent, 9000; Tobago, 4000; Santa Lucia, 10,200; Martinique, 75,000; Dominica, 3700; Guadeloupe, 35,088,944 *kilo.*; Antigua, 7700 hhds.;

St. Kitts, 10,600 ; Porto Rico, 140,030,000 lb. ; Jamaica, 29,074 hhds. Exports: Barbados, 1880, 54,217 hhds. sugar, 31,791 puns. molasses ; Jamaica, 1874, 28,398 hhds. sugar ; Dominica, 1871, 66,220 cwt. sugar, 94,015 gal. molasses ; Montserrat, 1871, 1891 hhds. sugar, 466 puns. molasses ; Trinidad, 1874, 99 million lb. sugar, 1½ million gal. molasses ; St. Croix, 1873, 10 million lb. sugar, 350,000 gal. molasses ; Porto Rico, 1873, 101,195 tons sugar, 6 million gal. molasses ; Cuba, 1873, 714,960 tons sugar, 189,333 tons molasses. Our imports from the British W. Indies were :—Unrefined : 3,242,034 cwt., 3,056,564*l.*, in 1879 ; 2,578,971 cwt., 2,738,322*l.*, in 1880 ; molasses : 137,405 cwt., 56,385*l.*, in 1879 ; 42,476 cwt., 16,937*l.*, in 1880. French W. Indies :—Refined : 28,095 cwt., 35,411*l.*, in 1876 ; unrefined : 116,993 cwt., 169,739*l.*, in 1879. Spanish W. Indies :—Unrefined : 2,260,193 cwt., 2,299,764*l.*, in 1879 ; 640,810 cwt., 770,673*l.*, in 1880 ; molasses : 37,303 cwt., 15,604*l.*, in 1876 ; 156 cwt., 35*l.*, in 1880.

Zanzibar.—Exported 3000*l.* worth in 1864.

Consumption.—Following are approximate statistics of consumption in various countries :—

	Year.	Aggregate Consumption.	Lb. per Head.
		cwt.	
United Kingdom	1875	18,374,543	62·80
Holland	1874	800,000	25·03
Belgium	1874	1,000,000	23·19
Hamburg (imports)	1873	1,223,733	..
Germany	1874	6,120,000	16·60
Denmark	1873	533,831	33·30
Sweden	1873	630,741	16·90
Norway	1873	193,086	12·70
France	1874	5,000,000	15·50
Austria and Hungary	1874	3,400,000	15·10
Switzerland	1873	381,295	15·90
Portugal	1874	300,000	8·40
Spain	1873	81,817	0·54
Russia and Poland	1874	4,000,000	5·40
Turkey	1874	500,000	3·80
Greece	1871	86,800	6·60
Italy	1873	865,350	3·60
United States	1873	13,040,500	37·80
British America	1875	1,721,386	51·40
Brazil	1874	642,857	8·00
Peru	1874	570,000	5·61
River Plate States	1874	1,000,000	43·90
Other S. and Central American States	1874	500,000	..
W. India Islands (British and Foreign)	1874	1,000,000	..
N. and S. Africa	1874	1,000,000	..
Australia	1874	1,713,142	85·90
India, China, and the Eastern and Pacific Islands	..	25,000,000	..

Values.—The approximate London market values of sugars, per cwt., are :—Jamaica : fine, 20–25*s.* ; good, 19*s.* 6*d.*–24*s.* 6*d.* ; middling, 19–24*s.* ; good brown, 18–23*s.* 6*d.* ; ordinary brown, 17–22*s.* Demerara, Trinidad, &c. : fine, 20–24*s.* ; good, 19*s.* 6*d.*–23*s.* 6*d.* ; middling, 18*s.* 6*d.*–23*s.* ; good brown, 17*s.* 6*d.*–22*s.* 6*d.* ; ordinary brown, 16*s.* 6*d.*–21*s.* 6*d.* ; crystallized, low, 23*s.* 6*d.*–30*s.* ; do. medium, 25–31*s.* ; do. good to choice, 27*s.* 6*d.*–33*s.* St. Lucia : good and fine, 19–24*s.* ; middling, 18*s.* 6*d.*–23*s.* ; brown, 16*s.* 6*d.*–22*s.* Barbados : low, 17*s.* 6*d.*–24*s.* ; middling to fine, 19–26*s.* 6*d.* ; grainy, 21*s.* 6*d.*–28*s.* 6*d.* Antigua, 17–24*s.* 6*d.* Concrete, 16*s.* 6*d.*–20*s.* Mauritius : crystallized, 23–29*s.* ; grainy yellow, 20*s.* 6*d.*–27*s.* ; yellow, 18*s.* 6*d.*–24*s.* 6*d.* ; brown, good and fine, 17*s.* 6*d.*–22*s.* ; brown, low, 16–20*s.* 6*d.* Benares, 23–25*s.* 6*d.* Bengal date : yellow to fine, 19–26*s.* 6*d.* ; brown, low to fine, 13*s.* 6*d.*–23*s.* ; Jaggery, 13–18*s.* Penang : yellow and white, 19–29*s.* ; brown, 16*s.* 6*d.*–22*s.* 6*d.* ; native, 13*s.* 6*d.*–17*s.* 6*d.* Natal, 14–29*s.* Egyptian : brown syrups, 15–20*s.* ; yellow do., 17*s.* 6*d.*–21*s.* 6*d.* ; white crystallized, 25–30*s.* Manilla : clayed, 16–21*s.* 6*d.* ; unclayed, 13*s.* 3*d.*–18*s.* 6*d.* Java : grey and white, 22–30*s.* ; brown and yellow, 17*s.* 6*d.*–26*s.* 6*d.* ; brown syrups, 13–15*s.* ; No. 14 to 15, afloat, 24–29*s.* China and Siam : yellow, 18*s.* 6*d.*–24*s.* 6*d.* ; brown, 14–22*s.* Porto Rico : good and fine, 20–25*s.* ; middling, 19–21*s.* ; brown, 17*s.* 6*d.*–18*s.* 6*d.* Brazil : white and grey, 20–26*s.* ; yellow, 18*s.* 6*d.*–24*s.* 6*d.* ; brown, 15–22*s.* Beet : French crystals, 25–27*s.* ; do. new 88 per cent., 21–25*s.* ; Austrian, 88 per cent., 20–25*s.* Refined : Titlers, 26–34*s.* ; loaves, 29–32*s.* ; cubes, 28–35*s.* ; pieces, fine, 21–31*s.* ; do. good and ordinary, 18–26*s.* ; bastards, 16–23*s.* ; Hamburg : crushed, 28–30*s.* 6*d.* ; treacle, 11–17*s.* ; Dutch : loaves, 25–28*s.* ; crushed, No. 1, 25–30*s.* ; Belgian : loaves, 26*s.* ; crushed, 25*s.* 6*d.* ; Paris loaves, 26–31*s.* Candy, 28–42*s.* Molasses : British W. Indian, 9–12*s.* ; Australian, 8–8*s.* 6*d.* ; British treacle, 13–16*s.*

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TANNIN (Fr., *Matières tannantes*; Ger., *Gerbstoffe*).

The word "tannin" does not, as formerly supposed, denote a single definite compound, but is a generic name applied to a large class of organic bodies, mostly uncrystallizable, which often differ widely both in chemical constitution and reaction, but have the common property of precipitating gelatine from its solution, and forming insoluble compounds with gelatine-yielding tissues. By virtue of this power, they convert animal hide into the insoluble and imputrescible material called "leather" (see pp. 1213–40). They all form blackish-blue or blackish-green compounds with ferric salts, and are precipitated by acetate of lead and of copper; but these properties are common to many other organic substances. They give insoluble precipitates with many organic bases, and with a large number of metallic salts. In some cases, the tannin combines with the base only, liberating the acid; but frequently the salt as a whole enters into combination. This is the case with the precipitates formed with acetates of lead and copper. With alkalies, the tannins and many of their derivatives give solutions which oxidize and darken rapidly, usually becoming successively orange, brown, and black. A. H. Allen has shown that these bodies also give instantaneously a deep-red coloration with a solution of potassium ferricyanide and ammonia. The reaction is one of considerable delicacy.

The tannins are very widely distributed through the vegetable kingdom. They are probably to be regarded in most cases rather as waste products eliminated by the plant, than as bodies stored up for future nutrition, like starch and sugar, and are enclosed in the tissue-cells.

General Chemistry.—A large number of plants, from every part of the world, contain principles varying in properties and constitution, but having the common characteristics of an astringent taste, of precipitating gelatine from solution, and of giving a blackish coloration with persalts of iron. The whole class are denominated "tannins;" but it is obvious that the different tannins are often widely distinct, and that the general statements frequently made are usually true only of certain individual members of the group. On the same grounds, it may also be concluded that any general method of analysis can only give arbitrary percentages, which afford no safe means of comparing tannins of different species, although it may be of considerable use in deciding the relative values of different samples of the same material.

From the tanner's point of view, tannins may be divided into two principal classes, viz. those which produce a light fawn-coloured deposit on leather (technically known as "bloom"), and those which do not. To the first of these, belong the tannins of gall-nuts, valonia, oak-bark, myrabolans, sumach, and divi-divi, while the second includes cutch, gambier, hemlock, larch, rhatany, and mangrove, and all the varieties of mimosa. Bearing in mind that the same plant frequently contains more than one species of tannin (of which the different characters of the tannins of gall-nuts, valonia, and oak-bark, all produced by oaks, is a striking example), it will appear that this classification is generally coincident with an important difference of chemical constitution; most tannins which give "bloom" are derivatives of gallic acid (see Acid—Gallic, pp. 50–1), while those which deposit insoluble red and brown colouring matters are derived from protocatechuic acid,—oak-bark and valonia excepted. To the chemical student, it may be interesting to note that both these bodies are benzene derivatives, belonging to the "aromatic" group of carbon compounds, of which benzene is the simplest type. Their relation is shown by the following formula:—

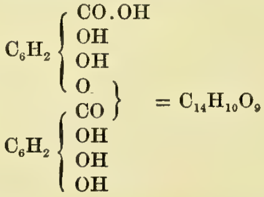
Benzene.	Gallic acid.	Protocatechuic acid.
C_6H_6	$C_6\left\{\begin{matrix}H_2\\(OH)_3\\CO.OH\end{matrix}\right. = C_7H_6O_5$	$C_6\left\{\begin{matrix}H_3\\(OH)_2\\CO.OH\end{matrix}\right. = C_7H_6O_4$

Stenhouse attempted some years since to separate tannins into two classes, according to the bluish- or greenish-black which they gave with persalts of iron. It has been shown that this is dependent in some cases on associated impurities, and it is influenced by the amount of acidity of the iron solution used, gallic and gallotannic acids giving a deep green coloration with strongly acid ferric chloride, while with ferric acetate they give a blue- or purple-black. As a general rule, however, it may be stated that the tannins which give a blue- or purple-black with ferric acetate are gallic-acid derivatives, and likely to give bloom to leather; while those which give a green-black are derived from protocatechuic acid, and will probably yield no bloom. Gallic and pyrogallic acids give with ferric acetate a purple-black; while protocatechuic and pyrocatechuic acids give a dark-green.

When natural tannins are boiled with dilute sulphuric acid, they are decomposed, generally yielding glucose, often also insoluble red bodies, called phlobaphenes. These bodies, when fused with caustic potash, give protocatechuic acid, and either acetic acid or a peculiar sugar called phloroglucine. Hlasiewetz gives the following table of the derivatives of tannin so treated:—

Source of Tannin.	Name of Tannin.	Products on boiling with Sulphuric Acid.	Product of the last column fused with Caustic Potash.
Gall-nuts	Gallotannic acid	Glucose and gallic acid	Pyrogallic and carbonic acids.
Pomegranate-bark, in company with gallotannic acid in sumach, myrabolans, &c. ..	Pomegranate tannin	„ ellagic „	Gallic acid (?)
Coffee	Caffetannic acid	„ caffeic „	Protocatechuic and acetic acids.
Cinchona-bark	Quinatannic „	„ quina red	„ „
„ „	Quinovatannic „	„ quinova „	„ „
Male fern	Filicitannic „	„ filix „	„ „
Rhatany-bark	Rhataniatannic „	„ rhatania „	Protocatechuic acid and phloroglucin.
Chestnut	Chestnut tannin	„ chestnut „	„ „
Cutch and gambier ..	.. ..	Catechin	„ „
Fustic (*Morus tinctoria*)	.. ..	Maclurin or morintannic acid	„ „

From Hlasiewetz's table, it would appear that a very large proportion of tannins yield glucose on digestion with a dilute mineral acid. They appear, however, to differ materially from the class of bodies known as glucosides, which are generally crystalline, and yield their glucose very easily under the influence of acids, while tannins (except perhaps morintannic acid) are amorphous, and require somewhat prolonged digestion. Hlasiewetz suggests that they may be "gummides," or compounds containing gum or dextrine, which is converted by digestion with acid into glucose (see pp. 1914–21). But it is by no means certain that glucose should be regarded as an essential constituent of tannins, since, by repeated precipitations with lead acetate, and decomposition of the tannate with sulphuretted hydrogen, gallotannic acid may be prepared almost free from any glucose, yielding constituent, and retaining all its characteristic properties. Schiff, by acting on gallic acid with phosphorus oxychloride, has produced gallotannic acid synthetically, and this artificial tannin yields no glucose, but only gallic acid, by digestion with acids. This synthesized tannin appears to be *di*gallic acid, formed from two molecules of gallic acid by the simple abstraction of one molecule of water. Thus, its constitutional formula is



$$\begin{array}{ll} C_6H_2 & \left\{\begin{array}{l}CO.OH\\ OH\\ OH\\ O\end{array}\right. \\ & \left.\begin{array}{l}\\ CO\end{array}\right\} = C_{14}H_{10}O_9 \\ C_6H_2 & \left\{\begin{array}{l}OH\\ OH\\ OH\end{array}\right. \end{array}$$

Natural gallotannic acid is probably a molecular compound of this digallic acid with glucose or dextrine.

In digesting ordinary gallotannic acid, from gall-nuts, sumach, myrabolans, and other sources, with sulphuric acid, or in its decomposition by natural fermentation, besides glucose and gallic acid, a varying quantity of a grey or fawn-coloured deposit of ellagic acid is always produced. This is closely allied to tannic (digallic) acid, differing from it only by the abstraction of 2 atoms of hydrogen, and may be produced from it by heating it with dry arsenic acid (which oxidizes the hydrogen). It is, however, probable that it is produced in the cases named from a peculiar tannic acid, called by Löwe ellagitannic acid, which exists in divi-divi, myrabolans, pomegranate-rind, and other materials, in mixture with ordinary gallotannic acid. This body is what Hlasiewetz calls "pomegranate tannin." Oak-bark and valonia yield abundant light-coloured deposits, which are probably ellagic acid.

On heating dry gallotannic or gallic acids to 180°–210° (356°–410° F.), they are decomposed, and partially sublime in white prismatic plates of pyrogallol, or pyrogallic acid, while a black residue of metagallic acid remains. By heating a solution of gallic acid in glycerine to 200° (392° F.), it is completely converted into pyrogallol, without production of metagallic acid.

Pyrogallol ($C_6H_6O_3$) has a feebly acid and very bitter flavour. It fuses at 131° (268° F.), is soluble in less than 3 parts of cold water, and still more soluble in hot. It is also soluble in alcohol and ether, but not in absolute chloroform. In presence of alkalies, it absorbs oxygen with great avidity, turning brown or black. It reduces Fehling's solution, and those of gold and silver, and gives purplish-blacks with ferric and ferrous salts. Probably its most characteristic reaction is the fine but very fleeting purple coloration which it gives with lime-water. Since all vegetable extracts containing gallic or gallotannic acids yield pyrogallol, its production has been used as a test for the presence of these bodies by Stenhouse, thus distinguishing again between the two classes of tannins derived from gallic and protocatechuic acids respectively. It is a singular fact that although oak-bark and valonia tannins give blue-blacks with iron salts, and yield abundant white deposits supposed to be ellagic acid, they give no pyrogallic acid on heating; but on the contrary, are stated by Johansen to yield protocatechuic acid on fusion with potash. They thus present important differences from gallotannic acid on the one hand and from most red-yielding tannins on the other, and urgently demand further investigation. Experiments made by the writer suggestt he probability that oak-bark tannin contains phloroglucin as well as protocatechuic acid.

Associated with different species of catechutannic acids in cutch and gambier, considerable portions of a white crystalline body (or possibly class of bodies) are found. This is catechin. It is contained in large quantity in cube gambier, forming a great part of the pale-coloured crystalline interior. It is readily soluble in boiling water, but very slightly so in cold; hence, on allowing a boiling solution of gambier to cool, it is deposited in large quantities as a whitish sediment. Its solution does not precipitate gelatine. Its relation to the tannins of cutch and gambier is not well made out, but they seem to be anhydrides. Its lower anhydrides are soluble in water, and precipitate gelatine; while with every successive molecule of water which they give up, they become more insoluble, and the higher anhydrides are reds similar to phlobaphene, insoluble in water and ether, but soluble in alcohol. Thus to an extent the relations between catechin and the catechu tannins are similar to those between gallic acid and gallotannic acid, but catechin is a body of much more complicated structure than gallic acid. Its formula is probably $C_{19}H_{18}O_8$, and both it and its anhydrides, when fused with potash, yield protocatechuic acid and phloroglucin.

It may be well to remark here that the question of hydration plays an important and imperfectly understood part in the chemistry of tannin. When hemlock tannin is reduced to a thick extract by evaporation in the vacuum-pan, it appears to part with some of its combined water, and a portion only of the tannin is soluble in cold water, the remainder being precipitated as an insoluble anhydride or phlobaphene, which cannot be dissolved even by subsequent boiling. If, on the other hand, water of as high a temperature is employed as has been used in the evaporation of the extract, the whole is brought again into solution, unless the extract has been thickened at too high a temperature. This is true of most tanning extracts besides hemlock.

It will thus be obvious that our knowledge of the chemistry of the various tannins is very imperfect, and it is useless to try to fill up the gaps by mere speculation.

As regards analytical examination of mixtures of tannins, a quantitative separation of the different species is as yet quite impossible; but qualitatively, tannins may at least be detected when not in too complicated mixture. The following table gives distinctive reactions of some of the principal tannins and their derivatives.

Reagent.	Gallotannic Acid.	Gallic Acid.	Pyrogallic Acid.	Oak Bark Infusion.	Solution Pegu Cutch.
Baric chloride and ammonia.	Blue ppt.	Blue ppt.	Brown coloration.	Brown ppt.	Slight ppt.
Bromine-water.	Nil.	Nil.	Nil.	Pale „	Dense buff ppt.
Lime-water.	Ppt. turning blue.	Ppt. turning blue.	Deep violet colour.	Brown „	Slight ppt., soluble in excess.
Copper sulphate.	Nil.	Nil.	Nil.	Slight „	Dense ppt.
Ferric acetate.	Blue-blk. ppt.	Purple-blk. ppt.	Purple-blk. colour.	Blue-blk. ppt.	Green-blk. ppt.
Lead nitrate.	White ppt.	Nil.	Nil.	Brown ppt.	Nil.
Gelatine.	Ppt.	Nil.	Nil.	Ppt.	Cloudy ppt.

The infusions used should be very dilute, not exceeding 5° of the barkometer (sp. gr. 1·004).

A. H. Allen, in his 'Commercial Organic Analysis,' gives the following table for the distinction of gallic, pyrogallic, and gallotannic acids:—

	Reagent.	Gallic Acid.	Pyrogallic Acid.	Gallotannic Acid.
1	With solution of gelatine.	No change except in presence of gum.	No change.	White or brownish ppt.
2	Heated with Fehling's solution.	No change.	Reduction and precipitation of Cu_2O.	Reduction and precipitation of Cu_2O.
3	With ferrous sulphate free from ferric salt.	White ppt. concentrated; no change dilute.	Blue solution.	White concentrated; no change dilute.
4	With ferric chloride.	Deep blue colour destroyed by boiling.	Red colour, turning brown when heated.	Blue-black ppt.; colour destroyed by boiling.
5	With excess of lime-water.	White precipitate becoming purple or deep brown very rapidly.	Immediate purple colour, changing to brown in the air.	White precipitate slowly darkening.

Quantitative Determination.—Many processes have been proposed for the quantitative estimation of tannins, but it cannot be said that any method yet known is wholly satisfactory. The oldest, that of Sir H. Davy, recently improved by Stoddart and others, consists in precipitating with gelatine, and drying and weighing the precipitate. This was almost impossible to filter off as directed by Davy; but by the use of a little alum, and by pouring hot water on the precipitate, it becomes curdled into a mass which may be washed by decantation. As the precipitate contains varying quantities of tannin, according to the strength of solution employed; as it is soluble in excess of gelatine solution, and as it is almost if not quite impossible to wash it free from gelatine and alum, the method can hardly lay claim to much accuracy. A somewhat better one consists in the employment of a standard solution of gelatine with a little alum, determining the end of the reaction by filtering off a portion and ascertaining if another drop of the reagent produces a further precipitate. This method is very tedious, the end reaction is difficult to hit, the standard solution is very unstable, it is inapplicable to gambier and cutch because the mixture will not filter clear, and its results are irregular, probably from the power of tannin to combine with various proportions of gelatine. A third plan, which has a most seductive appearance of simplicity, is that of Hammer; he takes the sp. gr., then absorbs the tannin with slightly moistened hide-raspings, again takes the sp. gr., and from the difference calculates the percentage of tannin, a difference of 5 per cent. of tannin corresponding to one of 1·020 sp. gr. (20° barkometer). Unfortunately the hide is more or less soluble in the liquor, and absorbs acids other than tannic with considerable energy; the moistening of the raspings introduces an error, and the smallness of the quantity to be measured makes a slight error completely vitiate the results. With extreme care, due corrections for temperature, for the water introduced with the raspings, and for their solubility, and by substituting evaporation of the infusions to dryness for mere calculation from their sp. gr., the method is useful as giving almost the only information obtainable as to the actual weight of tannin in any material capable of being absorbed by hide. It is, however, only suitable for use as a check on easier and more rapid methods, such as Löwenthal's, which give accurate relative results, but no information as to absolute weight of unknown tannins. A modification of Hammer's method has been introduced by Müntz and Ramspacher, in which the liquor whence the tannin is to be removed is forced through a piece of raw hide by pressure. This method, except that it is more rapid, has all the evils of Hammer's original in an intensified form, and gives such variable results as to be quite useless in practice.

Several other methods have been proposed: such as Gerland's, with a volumetric solution of tartar emetic, used in presence of ammonic chloride; Fleck's, by precipitation with acetate of copper, and subsequent washing with ammonic carbonate and gravimetric estimation, either of the tannate dried at 100° (212° F.), or of the oxide of copper left on ignition; and Carpene's, by precipitation with ammoniacal zinc acetate, and subsequent estimation with permanganate and indigo. These, though giving fairly accurate results on some tannins, are only of limited application. They may be passed over, as well as Jean's method with a volumetric solution of iodine in presence of sodic carbonate, and Allen's method with acetate of lead, which, though accurate, are somewhat tedious and difficult, and present no advantage over Löwenthal's improved process. This last is easy of execution, constant in results, and universally applicable. Before proceeding to describe it in detail, it may be well to give some hints as to the best modes of sampling and preparing tanning materials for analysis, since this is often more difficult and tedious than the actual analysis.

Sampling.—Samples should always be drawn from at least 10 sacks or separate parts of the bulk, and, in the case of valonia, special care should be taken to have a fair average quantity of "beard." If several sacks are spread in layers on a level floor, and then portions going quite to the ground are taken from several parts of the floor, this will be accomplished. Where samples must be dealt with which have not been specially drawn, it might be safest to weigh out from each the same proportion of beard and whole cups, bearing in mind that the beard is always the richest part of the valonia. In sampling myrabolans, it should be remembered that the poor and light nuts will rise to the top, and hence the hand should be plunged well into the sack. Grinding when practicable is probably best done in a small disintegrator, fitted with gratings. The material, of which some pounds must be used, is screened over a sieve of say 15 wires per in., and all coarser parts are returned to the mill till they will pass. The mill must grind into a close box, that no dust may be lost. The advantage of this plan is that samples can be ground without previous drying, and thus in many cases time may be saved and separate determination of moisture avoided. When this is not practicable, the sample of some lb. at least is ground in an ordinary bark-mill, well mixed, spread out flat on a floor or table, and several portions are taken as already described, say 50–100 *grm.* in all, and dried in a water- or air-oven at 100° (212° F.). The moisture is best determined, to save time, in a small separate portion of 10 *grm.*, which must be dried till it ceases to lose weight, and the loss taken as moisture. It must be weighed in a covered capsule, as it is very hygroscopic. When the larger portion of the sample has been dried some hours, it is passed twice through a good coffee-mill, and then returned to the oven till thoroughly dried, for which, 12–24 hours is generally sufficient. Another method sometimes convenient is to take each acorn, or each piece of bark of the sample to be tested, and snip a piece from it with a pair of tinners' shears, taking care that in the case of valonia the section runs right to the centre of the cup; and in bark, that fair shares of the outer and inner layers are taken. The reason for drying before grinding is, that unless hard dried, tanning materials cannot be passed through a small mill. Bark and valonia usually contain 12–16 per cent. of moisture.

Löwenthal's Process: Exhaustion.—10 *grm.* of valonia, 20–30 *grm.* of bark, or corresponding quantities of other materials, are boiled for 10 minutes with 250 *cc.* of distilled water, great care being taken at first to avoid frothing and boiling over. The clear liquid is then poured into a gauged flask, the residue is boiled up for 10 minutes, a second and a third time, with 250 *cc.* of water, and is finally rinsed into the flask, allowed to cool to 15° (59° F.), and made up to 1 *litre.* In the case of sumach, a little more boiling even than this is desirable. Another method is to boil for ½ hour with 250 *cc.* of water, then pour the whole on a filter, wash with boiling water so long as a drop of the filtrate blackens paper moistened with a dilute solution of ferric acetate, and finally make up to 1 *litre.* Many materials, however, clog the filter to such an extent that washing is almost impossible. Kathreiner uses 15 *litres* of water, and corresponding quantities of material, in a large steam-jacketed copper pan, for each exhaustion, making the weight up finally to 15 *kilos.*, and obtains very uniform and excellent results. With all materials which deposit ellagic acid or other insoluble derivatives, on cooling and standing, considerably higher results will be obtained if the titration be made as soon as the liquor is cold, than if it be allowed to stand 24 hours; in this respect, a uniform practice should be adhered to. Addition of ½ *cc.* of glacial acetic acid renders the infusions less liable to change.

Reagents.—Solutions are required of (1) Pure permaganate of potash, 1 *grm.* per *litre.* (2) Pure sulphindigotate of potash, 6 *grm.*, and concentrated sulphuric acid, 50 *grm.* per *litre.* (3) Pure oxalic acid, 10 *grm.* per *litre.* The sulphindigotate of potash (indigo carmine), must be filtered, and when oxidized by permanganate, should give a pure clear yellow, free from any trace of brown or orange. Any contamination with indigo purple, which gives brown oxidation-products, is quite fatal to the accuracy of the analysis. The permanganate solution is standardized by measuring 10 *cc.* of the (decinormal) oxalic acid solution, adding a little pure sulphuric acid and distilled water, warming to 58° (136° F.), and running in the permanganate till a faint permanent pink is produced, for which about 50–51 *cc.* should be required. The indigo-carmine solution should be of such strength that 14–16 *cc.* of permanganate are required to bleach the quantity employed, which may be 20–25 *cc.*, as convenient. (4) Gelatine solution: 25 *grm.* of gelatine or finest glue are dissolved in 1 *litre* of water, and saturated with table-salt. (5) Salt and acid solution: to a saturated solution of common salt, are added 50 *cc.* of concentrated hydrochloric acid per *litre.*

Actual Analysis.—25 *cc.* of indigo solution are diluted to about ¾ *litre* with distilled or good drinking-water in a white porcelain basin, and the permanganate solution is added drop by drop from a burette with constant stirring till the last trace of green disappears. Call the quantity of permanganate used A. 25 *cc.* of indigo solution and 10 *cc.* of the tannin infusion are treated as above. Let the quantity of permanganate be B. (If it exceeds 25 *cc.*, less tannin infusion must be taken, and the results calculated accordingly.) 100 *cc.* of the tannin infusion are well mixed with 50 *cc.* of gelatine solution, and then with 100 *cc.* of salt solution, shaken for some minutes, allowed to stand several hours, and filtered. The filtrate should be perfectly bright and clear. 50 *cc.* of this filtrate (=20 of original infusion) are titrated with permanganate and indigo as before described, the permanganate being run in *very* slowly, 5–6 minutes being taken for the process. Let this be called C; it is the amount required to oxidize the "not-tannin."

Then B − A − $\frac{1}{2}$(C − A) is the quantity of permanganate required to oxidize the tannin. 4·156 *grm.* of pure gallotannic acid (Neubauer) and 6·236 *grm.* of oak-bark tannin (Oser) are said to be equivalent to 6·3 *grm.* of oxalic acid, and these numbers may be used to calculate percentages; but as the equivalents of most tannins are unknown, it would probably be better simply to calculate out the equivalent percentage of oxalic acid, which does not differ sensibly from that of oak-bark tannin. Then calling T the permanganate consumed by the tannin of 10 *cc.* infusion, O that required by 10 *cc.* of the oxalic solution, and x the percentage, and supposing 10 *grm.* of substance to be employed, $O : T :: 100 : x$; or the quantity of permanganate required to oxidize the tannin, divided by that required to oxidize the oxalic acid, and multiplied by 100, gives the percentage. Gallic acid needs more permanganate than the same weight of tannic acid, or even than the quantity of tannic acid from which it is derived.

A slight error is introduced by the presence of a trace of oxidizable matter in the glue, and when very great accuracy is required, it is well to make a blank estimation of "not-tannin" without tannin infusion, and deduct $\frac{1}{2}$ of the permanganate consumed as a correction from the not-tannin; but this may usually be disregarded. Each titration should be made twice, and successive tests should not differ by more than 0·1 *cc.* of permanganate.

It is obvious that it is impossible by analysis to compare the relative values of different tannins, such as those of myrabolans and gambier, or hemlock and valonia. All analysis can reasonably be expected to do is to give the relative values of different samples of the same substance, or at the most, of materials of the same class. All other comparisons are misleading; and would be so, even if the exact percentage of each tannin could be calculated; since the commercial and practical value of different materials does not depend on the quantity of tannin only, but on the character of the leather it produces, hard or soft, dark- or light-coloured, and heavy- or light-weighing.

H. R. P.

Algarobilla.—The seed-pods of *Prosopis pallida* and *P. Algarrobo* are known as *algarobilla*, the two kinds being distinguished as *negro* and *blanco*. The trees are abundant in mountainous parts of S. America, notably Chili and the Argentine Republic. The pods contain up to 50 per cent. of a bright-yellow tannin, somewhat resembling that of myrabolans. The friable tannin is readily soluble in cold water, and is so loosely held in the fibrous network of the pod, that great loss is sustained by careless handling. The commerce in algarobilla does not figure in the official trade returns; but J. Gordon & Co., Liverpool, obligingly state that they imported 50 tons, at an average value of 18*l.* 10*s.* a ton, in 1880. Widow Duranty & Son, also of Liverpool, are good enough to add that they received 160 tons in 1881, the first that had reached them for a long time. Havre imported 50 tons in 1881.

The name *algarrobo* is also applied to *Balsamocarpon brevifolium* in Chili, and to *Hymenæa Courbaril* (see p. 1666) in Panama.

Chestnut-extract.—The wood of *Castanea vesca* (see Nuts—Chestnut, pp. 1352–3; Timber) contains 14–20 per cent. of a dull-brown tannin. It is quite different from the bark and bark-extract of the American chestnut-oak (*Quercus sessiliflora*). Its extract is used largely to modify the colour produced by hemlock-extract, and for tanning and dyeing. The pulverized wood is also extensively employed in France. The imports are included in barks and extracts, p. 1988.

Cork-bark. See Oak-barks.

Cutch, Catechu, or Terra Japonica (Fr., *Cachou*; Ger., *Catechu*).—The term *kát*, *kut*, or "cutch," is applied to the dried extract, containing 45–55 per cent. of dark-coloured mimotannic acid, prepared chiefly from two trees:—(1) *Acacia Catechu* [*Mimosa Catechu*, *M. sundra*], a tree of 30–40 ft., common in most parts of India and Burma, growing also in the hotter and drier districts of Ceylon, and abundant in tropical E. Africa—the Soudan, Sennar, Abyssinia, the Noer country and Mozambique, though the utilization of its tannin is restricted to India; (2) *A.* [*M.*] *Suma*, a large tree inhabiting S. India (Mysore), Bengal, and Gujerat.

The process for preparing cutch varies slightly in different districts. The trees are reckoned to be of proper age when their trunks are about 1 ft. diam. They are then cut down, and the whole of the woody part, with the exception of the smaller branches and the bark, is reduced to chips: some accounts state that only the darker heart-wood is thus used. The chips are placed with water in earthen jars, arranged in a series over a mud fire-place, usually in the open air. Here the water is made to boil, the liquor as it becomes thick and strong being decanted into another vessel, in which the evaporation is continued until the extract is sufficiently inspissated, when it is poured into moulds made of clay, or of leaves pinned together in the shape of cups, or in some districts on to a mat covered with the ashes of burnt cow-dung, the drying in each case being completed by exposure to the sun and air. The product is a dark-brown extract, which is the usual form in which cutch is known in Europe.

In Kumaon, N. India, a slight modification of the process affords a drug of very different appearance. Instead of evaporating the decoction to the condition of an extract, the inspissation is stopped at a certain point, and the liquor is allowed to cool, coagulate, and crystallize over twigs and leaves thrown into the pots for the purpose. By this method is obtained from each pot about 2 lb. of *kath* or catechu, of an ashy-whitish appearance. In Burma, the manufacture and export of cutch form one of the most important items of forest revenue. The quantity of cutch exported from the province in 1869–70 was 10,782 tons, valued at 193,602*l.*, of which, nearly half was the produce of manufactories situated in British territory. The article is imported in mats, bags, and boxes, often enveloped in the large leaf of *Dipterocarpus tuberculatus.* It is brought down from Berar and Nepal to Calcutta. That of Pegu has a high reputation.

Our imports of cutch in 1880 were 5155 tons, value 173,040*l.*, from the British E. Indies; 539 tons, 15,572*l.*, from other countries; total, 5694 tons, 188,612*l.* Our exports in the same year were :—892 tons, 28,527*l.*, to Germany; 676 tons, 24,562*l.*, to the United States; 478 tons, 15,505*l.*, to France; 303 tons, 10,537*l.*, to Holland; 177 tons, 5859*l.*, to Russia; 141 tons, 4835*l.*, to Belgium; 245 tons, 8719*l.*, to other countries; total, 2912 tons, 98,544*l.* The approximate London market value of Pegu cutch is 21–42*s.* a cwt.

An astringent extract prepared from the *Areca Catechu* (see Nuts—Areca, p. 1351) is said to contribute to commercial cutch; if so, it is a totally distinct product from those just described.

Divi-divi, or Libi-dibi.—These names are applied to the seed-pods of *Cæsalpinia coriaria*, a tree of 20–30 ft., indigenous to several of the W. Indies, Mexico, Venezuela, and N. Brazil, and naturalized in Madras and Bombay Presidencies, and in the N.-W. Provinces. The pod may be known by its drying to the shape of a letter S; it contains 30–50 per cent. of a peculiar tannin, somewhat similar to that of valonia. It is cheap, and may be used in admixture with barks; but it is dangerously liable to undergo fermentation, suddenly staining the leather a dark-red colour, and is therefore not in extensive use. The imports of it are mainly from Maracaibo, Paraiba, and St. Domingo. Maracaibo, in 1880, exported 197,674 lb. of divi-divi, value 3222¼ dol. (of 4*s.* 2*d.*), to New York. Our imports of divi-divi into Liverpool, according to figures kindly furnished by Haw and Co., were 2200 tons in 1877, 1740 in 1878, 2132 in 1879, and 780 in 1880. The approximate market value is 12–17*l.* a-ton.

Galls.—The generic term "gall" is applied to those excrescences on plants which are produced by the punctures of insects, for the purpose of depositing their eggs. The excrescences are usually considered to be a diseased condition of vegetable tissue, resulting from the injection of some secretion of the insects. But this has been combated by A. S. Wilson, of Aberdeen, who considers that all insect galls are in reality leaf-buds, or fruit-buds, and not mere amorphous excrescences. The vascular lines which would form leaves can easily be followed up in the structure of the oak-leaf galls. And in cases where the egg has been deposited in the tissue of a young branch, the cap of the gall is sometimes surmounted by a leaf 2–3 in. long. But in the large blue Turkish galls, many lacunæ occur where the fleshified leaves have not filled up the spaces between them. If a dissection be made of one of the weevil-galls on the bulb of the turnip, the second or third slice will show the outer foliations, exactly similar to those of the root-buds. When the centre has been reached, where the maggot will be found, there will also be a vascular pencil running up from a medullary ray in the bulb, and bearing on its top a bud of the same description as that produced by a ray running out from a root. The insertion of the ovipositor brings a medullary ray into action, producing a tuberculated bud, and it is only the bud which the larva feeds upon. The growth of a bud is an intelligible cause of the growth of a gall, but nothing can be inferred from the injection of a fluid. The analogy to leaves is further shown by the fact that various microscopic fungi are matured in the interior of imperforate galls.

The principal commercial kinds of gall are oak-galls and Chinese galls.

Oak-galls, Nut-galls, Aleppo or Turkey galls (FR., *Noix de Galle, Galle d'Alep*; GER., *Levantische* or *Aleppische Gallen, Galläpfel*).—These are formed by the punctures of *Cynips* [*Diplolepis*] *Gallæ tinctoriæ* on *Quercus lusitanica* var. *infectoria* [*Q. infectoria*], a shrubby tree of Greece, Cyprus, Asia Minor, and Syria, and probably other varieties and even species of oak. The female insect is furnished with a delicate ovipositor, by means of which she pierces the tender shoots of the tree, and lays her eggs therein. In the centre of the full-grown gall, the larva is hatched and undergoes its transformations, finally (in 5–6 months) becoming a winged insect, and boring for itself a cylindrical exit-hole. The best commercial galls are those which have been gathered while the insect is still in the larval state. Such have a dark olive-green colour, and are comparatively heavy; but after the fly has escaped, they become yellowish-brown in hue, and lighter. Hence they are distinguished in the London market as "blue" or "green," and "white." In Smyrna, they are classified as "white," "green," and "black," the first two sorts generally fetching nearly the same price, while the black obtain considerably more, the approximate quotations being :—white and green, per Turkish *oke* (of 2·83 lb.), 8½–9 *piastres* (of 2*d.*); black, 13½–14 *piastres.* The "nuts" come mostly from Melemen, Cassaba, and Magnesia, also from the Syrian coasts, being plentiful on the east of the river Jordan, and are chiefly forwarded to France, England, and Salonica. The triennial yield is said to be invariably the best. They begin to reach Smyrna from the interior towards the end of July. The crop of 1880 was estimated at over 50,000 *okes.* The province of Aleppo, which used to afford 10,000–12,000 *quintals* (of 2 cwt.) annually, only exported 3000 in 1871. The galls collected in the Kurdistan mountains are marketed at Diarbekir, and sent thence to Trebizonde for shipment. Bussora, Bagdad, and Bushire also export considerable quantities.

The exports from Aleppo (including yellow berries, see p. 864) in 1880 were :—60 tons, 3600*l.*, to Great Britain; 322 tons, 19,320*l.*, France; 15 tons, 900*l.*, Italy; 44 tons, 2640*l.*, Austria, 55 tons, 3300*l.*, Turkey; 30 tons, 1800*l.*, Egypt; total, 526 tons, 31,560*l.* In 1878, the figures were 673 tons, 38,400*l.* Alexandretta exported in 1879 (including yellow berries):—41 tons, 2460*l.*, to England; 299 tons, 17,940*l.*, France; 20 tons, 1200*l.*, Italy; 25 tons, 1500*l.*, Austria; 87 tons, 5220*l.*, Turkey; 6 tons, 360*l.*, Egypt; total, 478 tons, 28,680*l.* The shipments from Trebizonde by steamer in 1880 were (from Turkey):—47 sacks (of 2 cwt.), 188*l.*, to Turkey; 240 sacks, 960*l.*, Great Britain; 264 sacks, 1056*l.*, France; 103 sacks, 412*l.*, Austria and Germany; 26 sacks, 104*l.*, Greece; total, 680 sacks, 2720*l.*; (from Persia): 25 sacks, 100*l.*, Great Britain; 31 sacks, 124*l.*, France; 30 sacks, 120*l.*, Austria and Germany; total, 86 sacks, 344*l.* Bushire despatched 5000*r.* worth to India in 1879. Syra sent 248*l.* worth to Great Britain in 1879. Venice exported 1745 tons of galls and bark, value 34,906*l.*, in 1879.

The best oak-galls contain 60–70 per cent. of tannic or gallotannic acid, and 3 per cent. of gallic acid. "Rove" is a small crushed gall, containing 24–34 per cent. of gallotannic acid. There are many other varieties of non-commercial oak-gall.

Chinese or Japanese Galls.—These are vesicular protuberances formed on the leaf-stalks and branches of the *Rhus semialata* [*Bucki-amela*], a tree of 30–40 ft., common in N. India, China, and Japan, ascending the outer Himálaya and the Khasia Hills to 2500–6000 ft., by punctures of the female of *Aphis chinensis.* The galls are collected when their green colour is changing to yellow, and are then scalded. They are light and hollow, 1–2½ in. long, and of very varied and irregular form. The Japanese are the smaller and paler, and usually more esteemed. The galls contain about 70 per cent. of tannic or gallo-tannic acid, and 4 per cent. of another tannin. They are consumed mainly in Germany, for the manufacture of tannic acid.

Hankow exported 30,949 *piculs* (of 133⅓ lb.) in 1872; and 21,611 *piculs*, value 136,214 *taels* (of about 6*s.*), in 1874. In 1877, the total Chinese export did not exceed 17,515 *piculs.* Hankow exported 24,742½ *piculs* in 1878, and 28,392 *piculs*, 59,614*l.*, in 1879; Pakhoi, 62*l.* worth in 1879; Canton, 3155⅓ *piculs* in 1877, 1939 in 1878, 3163½ in 1879; Ichang, 100½ *piculs*, 132*l.*, in 1878, 402½ *piculs*, 586*l* , in 1879; Shanghae, 27,659½ *piculs* in 1879.

In China trade returns, they are always miscalled "nut-galls" or "gall-nuts": correctly, they are *wu-pei-tze.* Oak-galls are exported from China resembling those of W. Asia. Japanese galls, *kifushi*, are sent in increasing quantities from Hiogo.

Our imports of galls in 1880 were:—24,590 cwt., 68,697*l.*, from China; 17,311 cwt., 60,648*l.*, from Turkey; 9182 cwt., 9013*l.*, from other countries: total, 51,083 cwt., 138,358*l.* Our re-exports in the same year were:—6260 cwt., 18,479*l.*, to Holland; 6022 cwt., 18,147*l.*, to Germany; 3214 cwt., 11,002*l.*, to France; 3045 cwt., 8598*l.*, to Belgium; 2651 cwt., 11,004*l.*, to the United States; 1625 cwt., 5205*l.*, to other countries; total, 22,817 cwt., 72,435*l.* The approximate London market values of galls are:—Bussora, blue, 82–102*s.* a cwt.; do., white and in sorts, 50-90*s.*; China, 50–70*s.*; Japan, 55–56*s.*

Gambier, Pale Catechu, or Terra Japonica (Fr., *Gambir*, *Cachou jaune*; Ger., *Gambir*).—These names are conferred upon an extract from the leaves of *Uncaria Gambier* [*Nauclea Gambir*] and *U. acida*, containing 36–40 per cent. of a brown tannin, which rapidly penetrates leather, and tends to swell it, but alone gives a soft porous tannage; it is largely used in conjunction with other materials for tanning both dressing- and sole-leather. The plants are stout climbing shrubs, the first-named being a native of the countries bordering the Straits of Malacca, and especially the islands at the E. end, though apparently not indigenous to any of the islands of the volcanic band, growing also in Ceylon, where no use is made of it; while the second, probably a mere variety, flourishes in the Malay islands.

The shrubs are cultivated in plantations, often formed in jungle clearings; the soil is very rapidly exhausted, and further injured by excessive growth of the ineradicable *lalang*-grass (*Andropogon caricosus*). It is found advantageous to combine pepper-culture (see pp. 1812–4) with that of gambier, the boiled leaves of the latter forming excellent manure for the former. The gambier-plants are allowed to grow 8–10 ft. high, and as their foliage is always in season, each plant is stripped 3 or 4 times in the year. The tools and apparatus for the manufacture of the extract are of the most primitive description. A shallow cast-iron pan about 3 ft. across is built into an earthen fire-place. Water is poured into the pan, a fire is kindled, and the leaves and young shoots, freshly plucked, are scattered in, and boiled for about an hour. At the end of this time, they are thrown on to a capacious sloping trough, the lower end of which projects into the pan, and are squeezed with the hand so that the absorbed liquor may run back into the boiler. The decoction is then evaporated to the consistence of a thin syrup, and baled out into buckets.

When sufficiently cool, it is subjected to curious treatment: instead of simply stirring it round, the workman pushes a stick of soft wood in a sloping direction into each bucket; and, placing two such buckets before him, he works a stick up and down in each. The liquid thickens round the stick, and, the thickened portion being constantly rubbed off, while at the same time the whole is in motion, it gradually sets into a mass, a result which, it is said, would never be produced by simple stirring: it is reasonable to suppose that this manner of treating the liquor favours the crystallization of the catechin in a more concrete form than it might otherwise assume. The thickened mass, resembling soft yellowish clay, is now placed in shallow square boxes; when somewhat hardened, it is cut into cubes, and dried in the shade. The leaves are boiled a second time, and finally washed in water, which is saved for another operation.

A second plan is as follows:—The leaves are boiled, and bruised in a wooden mortar (*lesong*), from which they are put into a kind of basket of rattan open-work, which is pressed by a long piece of wood acting as a lever; the liquid is received into a trough, and there allowed to settle. When the sediment has acquired sufficient substance, it is put into a *kulit-kayo*, formed like a tub without a bottom, which lets the superfluous water drain off; when that is done, it is taken out, made into small cakes, and dried for use. A plantation employing 5 labourers contains 70,000–80,000 shrubs, and yields 40–50 *catties* (of $1\frac{1}{3}$ lb.) of gambier daily.

Plantations were commenced in Singapore in 1829, and once numbered 800; but owing to scarcity of fuel, abundance of which is essential to the manufacture, and dearness of labour, the culture was fast declining in 1866. In 1872, it had much recovered. It is largely pursued on the mainland (Johore), and in the Rhio-Lingga Archipelago, S.-E. of Singapore; on Bintang, the most northerly of the group, there were 1250 plantations of it in 1854. None is cultivated in Sarawak, though found wild in many parts; the foreign export from Sarawak in 1879 had a total value of 88,148 dol. The best kind is brought largely from Sumatra, but is often adulterated with sago. The Rhio product is also thus sophisticated, and rendered heavier by the Chinese purposely packing it in baskets lined with wet *cajangs*, occasioning a loss to the purchaser of about 30 per cent.

Singapore is the great emporium for gambier, and exported 34,248 tons in 1871, 19,550 tons having been imported, chiefly from Rhio and the Malay Peninsula. In 1876, the export increased to over 50,000 tons of pressed block, and 2700 tons of cubes. In 1877, it fell to 39,117 tons, owing to differences with the Chinese dealers concerning adulteration; of this quantity, 21,607 tons were for London, 7572 for Liverpool, and 2345 for Marseilles. The United Kingdom imports in 1872 were 21,155 tons, 451,737*l.*, almost all from the Straits Settlements; in 1880, they were 26,061 tons, 461,781*l.*, from the Straits, and 352 tons, 6468*l.*, from other countries; total, 26,413 tons, 468,249*l.* Our re-exports in 1880 were:—2487 tons, 48,507*l.*, to Holland; 1591 tons, 31,542*l.*, to Germany; 1137 tons, 23,694*l.*, to Russia; 594 tons, 12,026*l.*, to other countries; total, 5809 tons, 115,769*l.* The approximate London market values are 15*s.* 6*d.*–21*s.* 6*d.* a cwt. for block, 18–24*s.* for pressed cubes, and 23–27*s.* for free cubes.

Hemlock.—The bark of the hemlock or hemlock spruce (*Abies canadensis*), of Canada and the United States, contains nearly 14 per cent. of tannin. The stripping of the bark commences in the southern parts of the United States in spring, and lasts during April–May; in New York, Michigan, and Wisconsin, the season is June–July; and further north, it is still later. It is said that the best product is obtained furthest south. The destruction of the hemlock forests is fast approaching. Within the last 25 years, the preparation of an extract from the bark, containing 18–25 per cent. of a deep-red tannin, giving considerable weight and firmness to leather, has superseded the export of crude bark. The mode of preparing the extract is as follows:—The bark in pieces ½–1 in. thick, and several inches long, is soaked for about 15 minutes in water at 93° (200° F.); it is then fed into a hopper, which conducts it to a 3-roller machine, something like a sugar-cane mill (see p. 1873), through which it passes, coming out lacerated and compressed; it next falls into a vat of hot water, where it is agitated by a wheel, that the tannin from the crushed cells may be dissolved in the water; hence it is raised by a series of buckets on an endless chain, somewhat in the manner of a grain-elevator, to another hopper, whence it is fed to another 3-roller mill; here it receives its final compression, and comes out in flakes or sheets, like coarse paper, and almost free from tannin. The buckets are made of coarse wire, that the water may drip through during the elevation. In order to avoid the blackening action of iron, wherever this metal is brought into contact with the solutions it is thickly coated with zinc. The solution is evaporated to a solid consistency, generally by vacuum-pans. About 2 tons of bark are represented by 1 bar. (of less than 500 lb.) of extract. The chief makers are A. S. Thomas, Elmira, N.Y.; S. Brown & Co., New York; Canada Tanning Extract Co., St. Leonard and Bulstrode; J. Miller & Co., Millerton, New Brunswick. The total production is probably over 10,000 tons annually, ranging in value between 17*l.* and 23*l.* a ton. Our imports are included in barks and extracts, p. 1988.

Kino.—See Resinous and Gummy Substances, pp. 1667–8.

Mimosa- or Wattle-bark.—The bark of numerous species of *Acacia*, natives of Australia, contain considerable percentages of deep-red mimo-tannic acid, which forms a hard and heavy tannage if used strong, though soft upper-leathers may be tanned with it in weak liquors. The chief kinds are as follows:—The common wattle (*Acacia decurrens*), including its variety *A. mollissima*, is known also under the names of green, black, and feathery, but must not be confounded with the silver wattle (*A. dealbata*), though but doubtfully a distinct species. The bark is obtainable in vast abundance, and is much used by tanners. The trees are stripped in September and the two or three months following, and the bark, being allowed to dry, is then in a marketable condition. This tree, which grows in the uplands, affords a larger percentage of tannin than the silver wattle.

Blackwood or lightwood (*A. melanoxylon*) yields tanners' bark, which is inferior, however, to that from *A. decurrens*. The bark of *A. penninervis* yields of tannic acid 17·9 per cent., and of gallic acid 3·8 per cent. The bark of the native hickory (*A. suppurosa*) yields of tannic acid 6·6 per cent., and of gallic acid 1·2 per cent.

The bark of *A. saligna*, of S.-W. Australia, is much used by tanners, as it contains nearly 30 per cent. of mimo-tannin. *A. harpophylla*, of S. Queensland, furnishes a considerable share of the mercantile wattle-bark for tanning purposes. The bark of *A. lophantha* contains only about 8 per cent. of tannin.

The broad-leaved or golden wattle (*A. pycnantha*), of Victoria and S. Australia, deserves extensive cultivation. It is of rapid growth, will succeed even in sandy tracts, and yields seed copiously, which germinates with the greatest ease. The perfectly-dried bark contains about 25 per cent. of tannin. The aqueous infusion of the bark can be reduced by boiling to a dry extract, which in medicinal and other respects is equal to the best Indian cutch. It yields approximately 30 per cent. of tannin, about half of which, or more, is mimo-tannic acid. Probably no other tanning plants give so quick a return in cultivation as the *A. pycnantha* and *A. decurrens* of Australia. The latter varies in its proportions of tannin from 8 to 33 per cent. In the mercantile bark, the percentage is somewhat less, according to the state of its dryness, it retaining about 10 per cent. of moisture. The bark of the silver wattle (*A. dealbata*) is of less value, often even fetching only half the price of that of the black wattle. The bark improves by age and desiccation, and yields 40 per cent. of tannin, rather more than half of which is tannic acid.

Amongst all the kinds, the bark of the broad-leaved wattle is considered the most valuable, containing the greatest quantity of tannin; that of the silver wattle is not so valuable, being deficient in tannin; the black wattle is considered the most productive species; it can be barked at 8 years of age, and will produce 40–60 lb. dried bark, and full-grown trees will yield 100–150 lb. per tree.

The cultivation of wattles for commercial purposes has till now remained undeveloped; but no doubt, as soon as it is understood, the utilization of many acres of land lying waste, or which has already been exhausted and rendered unfit for the growth of cereals, will be effected by the cultivation of the wattle. It requires so little attention as to make it very profitable, and wattle-growing and grazing can be combined satisfactorily. After the first year, when the young trees in the plantation have reached the height of 3–4 ft., sheep can be turned in.

Wattles grow in almost any soil, even the poorest, but their growth is most rapid on loose sandy patches, or where the surface has been broken for agricultural purposes. When the soil is hard and firm, plough furrows should be made at a regular distance of 6–8 ft. apart, into which the seeds are dropped. The seed should be sown in May, having been previously soaked in hot water, a little below boiling temperature, in which they may be allowed to remain for a few hours. The seed should be dropped at an average distance of 1 ft. apart along the furrow, in which case, about 7200 seeds would suffice for one acre of land. The seed should not be covered with more than about ¼ in. of soil.

On loose sandy soil, it might even be unnecessary to break up the soil in any way: the furrows may be dispensed with, and the seed sown broadcast after the land is harrowed. After the plants have come up, they should be thinned so that they stand 6–8 ft. apart. When the young trees have attained the height of 3–4 ft., the lower branches should be pruned off, and every effort afterwards made to keep the stem straight and clear, in order to facilitate the stripping, and induce an increased yield of bark. It is advisable that the black and broad-leaved should be grown separately, as the black wattle, being of much larger and quicker growth, would oppress the slower-growing broad-leaved one. Care should be taken to replace every tree stripped by re-sowing, in order that there should be as little variation in the yield as possible. The months of September–December, in Victoria, are those in which the sap rises without intermission, and the bark is charged with tannin. Analysis proves that the bark from trees growing on limestone is greatly inferior in tannin to that obtained from other formations, differing 10–25 per cent.

The estimated expenditure on a wattle-bark plantation of 100 acres during 8 years is:—

	£	s.	d.
Rent of 100 acres for 8 years at 6*s.* per acre per annum	240	0	0
Ploughing 100 acres in drills 10 ft. apart	25	0	0
Sowing wattles and actual cultivation, including cost of seed	37	10	0
Supervision for 8 years (nominal), say 10*l.* per annum	80	0	0
Pruning the trees, taking off useless wood (necessary for 2 years), 10*s.* per annum	50	0	0
Incidental and unforeseen expenses	27	10	0
Interest on the whole amount expended during 8 years	240	0	0
	700	0	0
Actual cost of stripping and carting, as shown below	1515	0	0
	£2215	0	0

The receipts derivable from a wattle plantation of 100 acres, planted in the manner proposed, would be:—

	£	s.	d.
Each acre planted with wattles, 10 ft. apart, would carry 400 trees, and at end of 5th year trees would yield say 56 lb. matured bark: stripping only every 3rd tree, 332 trees would be obtained off 100 acres: this, at 4*l.* per ton, would give for 1st stripping	1332	0	0
In the 6th or following year, a similar number of trees would be stripped: the bark having increased in weight (say 14 lb.), the increased yield of 2nd stripping would be 400 tons at 4*l.* per ton ..	1600	0	0
In the 7th year, the remaining trees would be stripped, from which a still greater increase would be obtained, say 480 tons at 4*l.* per ton ..	1920	0	0
Total yield of bark	4852	0	0
The cost of stripping would not exceed 15*s.* per ton, on account of the facilities presented by the regularity of the trees, while carting would represent another 10*s.* per ton: these combined charges would be 25*s.* per ton, and on 1215 tons, would be	1515	0	0
Leaving a clear profit on the 100 acres of	£2637	0	0

The exports of mimosa-bark in 1876 were 11,899 tons from Victoria, 4758 from S. Australia, and 1735 from Tasmania. Later returns are included in barks, p. 1988. Shanghai imported 7038 *piculs* (of 133⅓ lb.) in 1879. The approximate London market values of mimosa-bark are:—Ground, 6–13*l.* a ton; chopped, 5–12*l.*; long, 5*l.*–9*l.* 10*s.* A very superior extract has been made from this bark.

Myrobalans or Myrabolams.—The fruits of several species of *Terminalia* constitute the myrobalans of commerce; they are chiefly *T. Chebula* and *T. Bellerica*, natives of India, the former being a tree 40–50 ft. high, and esteemed for its timber also. The fruits contain 30–35 per cent. of gallotannic acid, producing a soft and porous tannage, and good samples giving a bright-yellow colour. The tannin exists in the pulp, and is absent from the very hard "stone." The dried fruits are known locally as *har*, *harra*, or *bahera*, and are used commonly for dyeing, but not for tanning.

Our imports of myrobalans in 1880 were:—238,151 cwt., 121,465*l.*, from Bombay and Sind; 115,670 cwt., 51,339*l.*, from Madras; 11,020 cwt., 4717*l.*, from Bengal and Burma; 3520 cwt., 1402*l.*, from other countries; total, 368,361 cwt., 178,923*l.* Our re-exports in 1880 were 8015 cwt., 4328*l.*, to Germany; 16,127 cwt., 8515*l.*, to other countries; total, 24,142 cwt., 12,843*l.* The approximate London market values of myrobalans are 7–14*s.* a cwt. for good, and 5–10*s.* for common. Shanghai imported 4403 *piculs* (of 133⅓ lb.) in 1879.

Oak-barks (Fr., *Écorces de Chêne*; Ger., *Eichenrinden*).—The barks of several species of oak have valuable tanning properties. They are chiefly:—The common oak (*Quercus Robur*), which is of even greater importance as a timber-tree (see Timber—Oak); the cork oak (*Q. Suber*), described at length under Cork (see pp. 722–9); the evergreen oak (*Q. Ilex*); and the American chestnut-oak (*Q. sessiliflora*). These barks are among the most esteemed tannins as regards quality of leather, but are incapable of giving much weight, and from their bulk are costly to handle, containing only 10–12 per cent. of tannin (quercitannic acid). They give a reddish fawn-coloured leather, and deposit a good deal of bloom, but yield no gallic acid. The barks of the cork-oak and evergreen oak from S. Europe, are stronger and darker-coloured than English bark. The American chestnut-oak contains a peculiar fluorescent principle like æsculin.

Our imports of unspecified barks for tanners' and dyers' use in 1880 were:—189,399 cwt., 101,108*l.*, from Australia; 123,302 cwt., 32,974*l.*, Belgium; 57,232 cwt., 20,988*l.*, United States; 22,100 cwt., 6030*l.*, Holland; 18,648 cwt., 3676*l.*, Italy; 16,151 cwt., 6972*l.*, Algeria; 22,669 cwt., 8838*l.*, other countries; total, 449,501 cwt., 180,586*l.* Our imports of unenumerated bark-extracts in the same year were valued at:—516,578*l.* from Holland, 92,654*l.* France, 30,187*l.* United States, 16,315*l.* British N. America, 12,796*l.* Belgium, 13,769*l.* other countries; total, 682,299*l.* Our re-exports of barks in 1880 were:—19,548 cwt., 10,348*l.*, to Germany; 14,627 cwt., 7425*l.*, France; 4555 cwt., 3041*l.*, Holland; 10,304 cwt., 6080*l.*, other countries; total, 49,034 cwt., 26,894*l.*

With regard to cork-tree bark, James Gordon & Co., Liverpool, obligingly write that very little comes to England, the great bulk going direct to Ireland, where the consumption is large. The imports at Liverpool in 1880 were 186 tons, average value 8*l.* per ton. Of oak-bark, Hungary, in 1877, produced 25,000 tons, of which, 20,000 were exported to Germany for tanning purposes. The approximate London market values of oak-bark are:—English, 12–16*l.* per load of 45 cwt.; Foreign, tree, 5–8*l.* a ton; ditto, coppice, 6–8*l.* In 1879, Algiers exported 12,660,047 *kilo.* (of 2·2 lb.) of tanning bark.

Quebracho.—The local name *quebracho*, contracted from *quebra-hacho* ("axe-breaker"), is applied to several S. American trees possessing hard wood, belonging to distinct genera. They are chiefly as follows:—(1) *Aspidosperma Quebracho*, the *quebracho blanco*, a tree growing in the province of Catamarca, Argentine Republic; (2) *Loxopterygium* [*Quebrachia*] *Lorentzii*, the *quebracho colorado*, most prevalent in the province of Corrientes, the wood and bark of which come largely into commerce as tanning materials; (3) *Iodina rhombifolia*, the *quebracho flojo*, whose wood and bark are mixed with those of No. 2; (4) *Machærium fertile* [*Tipuana speciosa*], the *tipa*, which affords both wood and bark of less tanning value than No. 2. It would seem that the wood and bark of No. 2 are by far the most largely employed, containing 15–23 per cent. of a bright-red tannin. The wood and an extract from it are imported into Europe.

From information kindly furnished by James Gordon & Co., and Haw & Co., of Liverpool, it appears that the imports of quebracho-wood into Liverpool in 1880 were 200 tons, value about 4*l.* 10*s.* a ton; and of quebracho-bark, about 20 tons, none of which had been sold.

Sumach or Shumac (Fr., *Sumac*; Ger., *Gerbersumach*, *Schmack*).—The commercial term "sumach" is applied to the dried leaves of a number of S. European and American tannin-yielding plants. These are chiefly as follows:—In Sicily, the European or tanning-sumach (*Rhus Coriaria*); in Tuscany, *R. Coriaria*, often adulterated with leaves of *Pistacia lentiscus*; in Spain, several *Rhus spp.*, the products being divided into 3 kinds—Malaga or Priego, Malina, and Valladolid; in the Tyrol, the smoke-tree or fragrant or Venetian sumach (*R. Cotinus*); in France, *Coriaria myrtifolia*, divided into 4 sorts—*fauvis*, *douzère*, *redoul* or *redon*, and *pudis*, in Algeria, Tezera sumach (*R. pentaphylla*), used by the Arabs for making morocco-leather; in N. America, the smooth or white sumach (*R. glabra*), the Canadian sumach (*R. canadensis*), the staghorn sumach (*R. typhina*), and the dwarf or black sumach (*R. copallina*). These are found growing wild in the countries indicated, and are further subjected to cultivation in some districts, notably in Sicily. *R. glabra* and *R. copallina* are recommended chiefly for extended cultivation in the United States.

The soil usually chosen for cultivation of the plants is poor and light; but a much larger crop of leaves can be secured from strong, rich, deep soils, and it is generally admitted that the product in the latter case is also better. In Italy, limestone soils are considered to be especially suited to this culture, but the American varieties appear to be well adapted to sandy and clay soils as well. The primary requisite in a soil is that it should be well drained, the presence of stagnant water about the roots being exceedingly prejudicial. To prepare the soil for planting, it is ploughed as deeply as possible, and laid out in rows about 2 ft. apart. In Italy, small holes are made about 2 ft. long, 7 in. wide, and 5 in. deep, and a plant is inserted at each end. A more convenient method would consist in marking the field in shallow furrows in one direction 2 ft. apart, and then, with a heavy plough, tolerably deep furrows the same distance apart as, and at right angles to, the first. A plant may then be placed in the deep furrows at each intersection, the furrow again filled with the plough, and the earth pressed about the plant with the foot. If this were done in early spring-time, as soon as the earth is sufficiently dry to be conveniently worked, there can be no doubt that it would be successful, while it would certainly involve little cost. Plants are generally propagated from the young shoots which form each year about the base of an older plant, but may also be produced from cuttings made from young well-ripened wood, rooted by setting in a nursery or in frames, as in the propagation of grape-vines from cuttings. This latter method is scarcely ever required, however, when the cultivation has been started. Plants are also raised from seed, and seedlings are always found to be strong, vigorous, and thoroughly hardy; but on account of the greater time and labour involved in their production, this method of propagation has not received extended application. The first-mentioned generally gives the quickest, and probably most satisfactory results.

In selecting plants from any source, there are certain points to be observed:—(1) The shoots should come from young vigorous plants; (2) they should be over 1 ft. long; (3) those with large roots and few rootlets should be rejected; (4) those having white roots, covered with a fibrous, white, silky down, are also to be rejected, this being an indication of the presence of a very injurious subterranean parasitic fungus, capable of destroying the entire crop; (5) a good shoot is straight, at least ½ in. diam., 18 in. long, furnished with numerous buds close to each other, root short, but covered with rootlets. Shoots for planting may be collected in autumn, after the leaves have fallen, and be preserved in a nursery until spring; or this may be done in early spring, when the ground is very moist and soft. In either case, care should be observed that the rootlets are not injured by drying, or from any other cause.

The culture to be given the plant is somewhat similar to that required by Indian corn: the earth about it should be kept tolerably mellow and free from weeds, and such conditions can probably be maintained to a degree sufficient for sumach, by working several times during the growing season with a cultivator, and passing through the rows occasionally with a plough. All this work is not absolutely necessary to the life of the plant, but its vigour, and consequently its yield in leaves, may be considerably increased and strengthened thereby. After the first year, the number of operations may be diminished, but they should always be sufficient to keep the ground free from weeds and grass.

Shortly after planting, and when the plant is well set, the stock is pruned to a length of 6–8 in., when the plant is left to assume any form, and is no further pruned except by the process of collecting the leaves, unless hand-picking is resorted to; in such case, after the 2nd year, pruning takes place each year in the fall or winter, the plant being reduced to a height of 6–10 in. After the 3rd year, the plant begins to produce the shoots from about its base, already mentioned; these, if not needed for new plantations, should be removed each year, for if left to develop, they weaken the plant. If not removed during the summer, the operation should without fail be effected during the fall or winter.

The 1st crop of leaves may be secured during the year following that of planting. This develops and matures somewhat later than that from older plants, and in Italy it is not collected until the end of August or the 1st of September; but there are reasons for believing that in the United States, especially in the N. States, the collection of leaves from native varieties should be made much earlier, because the summer is much shorter, and the habits of the varieties grown differ from the Sicilian. All the leaves, except the young and tender ones of the extremities of the branches, are stripped off and placed in baskets, in which they are carried to a threshing-floor, where they are spread out in thin layers to dry. Here they must be frequently stirred and turned over, for which purpose a fork with wooden prongs is employed. In the fall, when grow this finished, and before the leaves have had time to become red, those remaining on the extremities are collected. To this end, the branches are broken just below the tuft of leaves, and the latter are allowed to remain suspended to the branch by a piece of bark not detached, and left in this condition until nearly or quite dry. They are then collected and treated in the same manner as other leaves, but the product obtained in this way is always of inferior quality.

After the 2nd year, crops of larger quantity and superior quality are obtained, and the collection is made in a different way, and much more frequently. The two methods followed in Sicily are (1) pruning, and (2) defoliation. The first, which is the more ancient, but much less costly, requires less care, and is simple and rapid; but it is injurious to the future condition of the plant, and the quantity of subsequent crops. The second, though slower, serves to better maintain the vigour of the plant, and the uniform quantity of the crop from year to year; in consequence, it reduces the necessity for frequent renewal of stocks.

Harvest by pruning is carried on in Italy as follows. During May, the lower leaves, which, from greater age, appear to have attained full maturity, and may be in danger of loss from falling, are removed in the same manner as described for collecting the leaves from yearling plants. Toward the end of June, and during the course of July, all branches bearing leaves are cut away, reducing the plant to the principal stock: by this means, the crop is harvested and the plant is pruned at the same time. But even in Sicily, the time for this operation is limited to no absolute period, and varies with the development of the leaf, as indicated by cessation of growth and increase in size. In this condition, also, the leaves will have acquired their deepest green colour, and attained their maximum weight and best quality. It is further stated that while this time varies according to locality, about Palermo it is never earlier than June nor later than July. The harvest by pruning must always be made by men accustomed to the work, and equal to the exertion required. Provided with a pruning-bill, they cut off all leaf-bearing branches, collecting them on the left arm, until each has cut as much as he can conveniently carry, when he places the armful on the ground with the butts in the direction of the prevailing wind, which, if tolerably strong, might carry away some of the leaves if turned in the opposite direction; finally, he presses down the branches with his foot, to make the heap more compact, and leave less surface exposed to the wind and sun. Another labourer deposits a second armful in the same place, presses it with his foot in like manner, and the two deposits constitute a bundle. At the close of the operation, there remain the young shoots which are formed about the base of the plant, the leaves of which are not fully developed, and consequently not fit for collection until at least 20 days later. After this time, they are removed by hand, care being observed not to injure the buds, especially if the shoots are to be used for stocks in the formation of plantations of the following year.

Defoliation, or collection by hand, is carried on whenever the leaf may be fully developed and ripe, beginning at first with the lower leaves, and continuing eventually to the ends of the branches. It takes place at 3 different times during the season: the 1st in May, the 2nd late in July or early August, and the 3rd in September. At the last collection, the extremities of the branches are broken down, and the leaves are allowed to dry before removal from the plant, as described under collections of the 2nd year. In the application of this method, the regular pruning is effected during the fall or winter, when the plant is dormant, and under such conditions the operation becomes a regenerative one, giving in this particular an advantage over the other method, in which the pruning is effected in the summer when the plant is in full vegetative activity, and so has a strongly deteriorating influence. In both methods of pruning, care should be observed to leave a long slanting section, upon which, water will be less likely to settle and promote decay.

The leaves collected by either method are dried in the open field where they have grown, and when dried, are carried to a threshing-floor to be beaten, or at once to the threshing-floor and dried there. In the former, the operation is rather more rapid, but there is greater danger of injury by rain, the effect of which is very deleterious, especially if it fall upon the leaves when they are partially dried. The damage resulting from this cause is less if the leaves are not lying upon the ground, and are so arranged that the air may circulate freely about and under them. In the pruning method, the leaves are dried upon the branches and in the heaps where they are first deposited. Sometimes they are turned, but generally it is considered better not to disturb them until completely dried, and ready for transportation to the threshing-floor. In this way, they are protected to a greater extent from the action of direct sunlight, which is said to be injurious to the quality of the product. When the leaves are collected by hand, they are dried upon the threshing-floor, where they are spread in thin layers, and stirred 3–4 times a day. They are then beaten with a flail to separate the leaves from the branches and stems. If this be done during the middle of the day, when the leaves are most thoroughly dry and consequently brittle, they are reduced to small particles, producing what is called "sumach for grinding." But if it be done in the morning, or on damp days, when the air is charged with moisture and the leaves are tough, they are separated from the stems more nearly entire and less broken, and the product obtained is called "sumach for baling." The stems remaining after the separation of sumach for baling still retain small particles of leaves attached to them, and they are therefore again beaten when perfectly dry for the production of a low-grade sumach, called by the Italians *gammuzza*. The products are classed as follows:—

Sumach for baling	relative market value		2·5
„ „ grinding	„	„	2·3
„ from yearling plants	„	„	1·5
„ „ ends of branches collected in autumn	„	„	1·0

To prepare these different grades for ultimate consumption, they are ground in mills similar to those employed for crushing olives, that is, in which two large stone wheels follow each other, revolving upon a circular bed, the whole construction being about the same as the Spanish or Mexican arrastre. The sumach thus pulverized is passed through bolting-screens, to separate the finer from the coarser particles.

In Virginia, the leaves are collected and cured by the country people, and sold and delivered to owners of mills for grinding. Their particular object being to secure the largest possible quantity of product at the lowest cost, little attention is given to the quality obtained, or the manner of collecting. The most intelligent dealers in the raw material urge upon collectors to observe the following particulars:—The leaf should be taken when full of sap, before it has turned red, has begun to wither, or has been effected by frost, to ensure a maximum value for tanning purposes. Either the leaf-bearing stems may be stripped off, or the entire stalk may be cut away, and the leaves upon it allowed to wither before being carried to the drying shed; but care must be observed that they are neither scorched nor bleached by the sun. When wilted, they are carried to a covered place, and spread upon open shelving or racks to dry, avoiding the deposit in any one place of a quantity so great as to endanger the quality of the product by overheating and fermentation. Sumach should be allowed to remain within the drying-house at least one month before sending to the market; in case of bad weather, a longer period may be required. When ready for packing for shipment, it should be perfectly dry and very brittle, otherwise it is likely to suffer injury in warehouses from heating and fermentation.

Buyers of sumach leaves for grinding depend largely upon colour for the determination of the value; the leaves should, therefore, when ready for market, present a bright-green colour, which is evidence that they have suffered neither from rain after being gathered, nor from heating during the process of drying. Leaves having a mouldy odour or appearance are rejected. The Virginian crop reaches 7000–8000 tons, and is collected at any time between July 1 and the appearance of frost.

There is an important difference in the value of the European and American products. The proportion of tannic acid in the latter exceeds that found in the former by 6–8 per cent., yet the former is much preferred by tanners and dyers. By using Sicilian sumach it is possible to make the finer white leathers, so much used for gloves and fancy shoes; while by the employment of the American product, the leather has a disagreeable yellow or dark colour, apparently due to a colouring matter, which, according to Loewe, consists of quercitrin and quercetin, and exists in larger quantity in the American than in the Sicilian.

The experimental results obtained by collecting sumach at different seasons were :—

Virginia, mixed, collected in	June, gave	.. ..	22·75 per cent. of tannic acid.
,, ,, ,,	July, ,,	.. ..	27·38 ,, ,,
,, *R. glabra* ,,	August, ,,	.. ..	23·56 ,, ,,
,, *R. copallina* ,,	,, ,,	.. ..	16·99 ,, ,,
Sicilian, *R. Coriaria* ,,	,, ,,	.. ..	24·27 ,, ,,

It is evident, therefore, that in order to secure the maximum amount of tannic acid, the sumach should be collected in July, but the colouring matter of the leaves has an important influence upon the value of the product. The leaves of the upper extremities of the stalks are always richer in tannic acid than those of the base; and the increase of age of the plant is accompanied by a general diminution of this acid. Yet the collection of the crop should be delayed as long as possible, because the diminution of tannin in the leaves will be abundantly compensated for by the quality of the product.

Experiments upon the presence of colouring matters were made by treating gelatine solutions, and gave the following results :—

Virginia, mixed, collected in	June, gave	.. A nearly white precipitate.
,, ,, ,,	July, ,,	.. A decidedly yellowish-white precipitate.
,, *R. copallina,* ,,	August, ,,	.. A dirty-yellow precipitate.
,, *R. glabra,* ,,	,, ,,	.. A very dirty-white precipitate.
Fredericksburg mixed, ,,	,, ,,	.. A dirty-yellow precipitate.
Sicilian ,,	,, ,,	.. A slightly yellowish-white precipitate.

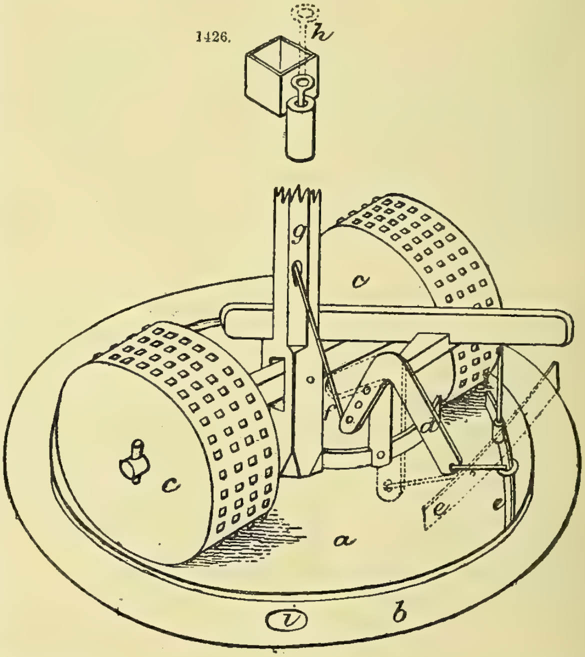
It is therefore advised that for the purpose of tanning white and delicately-coloured leathers, the collection should be made in June; while for tanning dark-coloured leathers, and for dyeing and calico-printing in dark colours, where the slightly yellow colour will have no injurious effect, the collection be made in July. It appears that for all purposes, the sumach collected after the 1st of August is inferior in quality.

Fig. 1426 shows a mill for grinding sumach-leaves; it consists of a heavy solid circular wooden bed *a*, 15 ft. diam., with a depression around the edge *b*, a few inches deep and 1 ft. wide, for the reception of the ground sumach from the bed, and 2 edge-rollers *c*, weighing about 2500 lb. each, 5–6 ft. diam., and provided with numerous teeth of iron or wood, thickly inserted. Most mills have to be stopped to allow the unloading of the bed, but this delay is obviated by an apparatus consisting of an angular arm *d*, attached to a scraper *e*, and worked by a lever *f*, which passes through the hollow shaft *g* and extends to the room above, where it terminates in a handle *h*. The scraper carries the ground sumach to the opening *i*, whence it is taken by an elevator to a revolving sieve or screen in a room above. After screening, the sumach is packed in bags, 15 to the ton, being always sold by that weight. The chasers and beds are inclosed in a case or drum, and the grinding is done by the application of power to the upright shaft *g*. The mills are fed from above. The packing is sometimes done by machinery alone. The best mills cost about 600*l*. In Europe, and in some parts of the S. States, sumach is still ground by stones revolving on a stone bed, and the sifting is often done by hand.

E. Coez & Co., St. Denis, near Paris, make a sumach extract. It is concentrated to a syrupy consistence in a vacuum-pan, and keeps well, exhibiting none of the acidity which is manifested by a simple decoction of sumach leaves. Sumach contains 16–24 per cent. of gallotannic acid, and is somewhat similar in tanning properties to myrobalans, but paler in colour. It is principally used for tanning morocco and other fancy leathers.

The district of Ancona yields 200 tons per annum of sumach, said to be equal to and cheaper than the Sicilian, but mostly consumed locally. Palermo exported of "ventilated" sumach to the United States 120,043 bags (14 = 1 ton) in 1877, and 50,085 in 1878, the average value being 14*l.* a ton. Trieste exported 7800 cwt. by land in 1877; in 1878, the shipments to England were 16,600 *kilo.* (of 2·2 lb.), value 1328 fl. (of 2*s.*), and in 1880, 91,800 *kilo.*, 7344 fl. Rustchuk in 1880 exported 1400 tons, chiefly to Roumania and Austria. Our imports in 1880 were 10,573 tons, 133,249*l.*, from Italy, and 1047 tons, 12,416*l.*, from other countries; total, 11,620 tons, 145,665*l.* The approximate London market value is 15*s.*–16*s.* 6*d.* a cwt. for Sicilian, 10–11*s.* for Spanish.

1426.



Valonia (Fr., *Vélanèdes*; Ger., *Valonia*). This is the commercial name for the large pericarps or acorn-cups of several species or varieties of oak, chiefly *Quercus Ægilops* and *Q. macrolepis.* The former is found growing in the highlands of the Morea, Roumelia, the Greek Archipelago, Asia Minor, and Palestine; the latter constitutes vast forests in many parts of Greece, and especially on the lower slopes of Taygetos, towards Ætylon and Mani (Laconia). Prof. Orphanides, of Athens, alludes to a third species or variety called *porto galussa*, which yields a superior kind of valonia, and named by him *Q. stenophylla.* The chief localities of production in Asia Minor are Ushak, Borlo, Demirdji, Ghiördes, Adala, Nazlü, Buldur, Sokia, Balat, Troja, Aivalik, and Mytilene. The annual exports, mainly from Smyrna, reach 600,000 *quintals* (of 2 cwt.), value about 400,000*l.* In Greece, the production is chiefly centred in the following districts: (1) The province of Lacedemonia, which afforded 10,000 cwt. in 1872; (2) the province of Gythium, in the lower part of Mount Taygetos, which gave 60,000 cwt. in 1872; (3) the island of Zea, which formerly yielded 30,000-40,000 cwt., lately reduced to 15,000 cwt. yearly; (4) Attica, especially the neighbourhood of Cacossalessi, grows 3000–5000 cwt., shipped from Oropos, in the Strait of Chalcis; (5) the island of Eubœa, whence about 1000 cwt. are shipped annually at Bouffalo; (6) the province of Triphyllia raises 3000 cwt., which go to Trieste, viâ Cyparissie; (7) the province of Pulos, especially the commune of Ligudista, grows over 2000 cwt., despatched from Navarino to Trieste; (8) the province of Achaia has a yearly crop of 30,000–40,000 cwt., shipped to Trieste from Courupeli and Caravostassi, between Patras and Cape Papa; (9) the small towns of Anatolico and Astakos (Dragomestre) collect the valonia of the eastern parts of Ætylon, Acarnania, and Cravassaras (a port in the Gulf of Arta), and of all the other western parts, to be sent to Trieste for shipment to England and Italy. Ætolia and Acarnania furnish abundant crops, that of 1872 exceeding 100,000 cwt. The total area of the Greek valonia-yielding forests is said to be about 13,000 *stremme* (of 119½ sq. yd.). The total production in 1877 was estimated at 2,601,000 *quintals* (of 2 cwt.); the greater part is exported, about ⅔ going to Austria, and the rest to Italy and England. The proportions of tannic acid in the valonia from different districts of Greece are said to vary as follows: Patras, 19–28½ per cent.; Gythium, 27¼–35½; Zea, 12¼–25¼; Vonitza, 18–20.

In Turkey, the fruit ripens in July–August, when the trees are beaten, and the fallen acorns left on the ground to dry. The natives afterwards gather them, and transport them on camel-back to stores in the towns, whence they go by camel and train to Smyrna, and are there placed in heaps 5–6 ft. deep in large airy stores for some weeks, during which the mass heats, and the acorn itself, which contains but little tannin, and is used for feeding pigs, contracts and falls from the cup. This incipient fermentation is attended with considerable risk; if carried too far, a large proportion of the valonia becomes dark-coloured and otherwise damaged. When ready for shipment, the heaps are hand-picked, the best being reserved for the Austrian market (Trieste), and the rest going to

England. In some cases, the rubbish having been removed, the remainder is known as "natural," and is thus exported to England.

In Greek commerce, three qualities are distinguished, *chamada*, *rhabdisto*, and *charchala*. The *chamada* (*camata* and *camatina* of Asia Minor) is the best; it is collected in April, before the acorn is matured, hence the cup which encloses the acorn is small and incompletely developed. The *rhabdisto* is the second quality; it is collected in September–October, and is distinguished by the fruit being larger and riper; the name means "beaten," the fruits being beaten down from the trees with sticks. After mid-October the collection ceases, because the first rains cause the fallen fruit to ferment or turn black, and they then take the name of *charchala*. They are distinguished by the cups being completely open, and containing no acorns. They are considered much inferior, possessing little tannin.

Sometimes the acorn cup is attacked by a kind of honey-dew, which deposits on the cup, and makes it very liable to heat when gathered, the cup becoming very dark and deficient in tannin. The Turkish crop of 1875 was much damaged from this cause, many parcels reaching England in an unsaleable condition. The cause of the disease is yet unknown; it seems specially prevalent when the crop is large and the acorn fully developed. A good sample of valonia should be composed of medium-sized cups, with the rim or wall very thick, and the exterior spines small and uniform. The cut or broken cup should show a bright-drab fractured surface. Valonia contains 25–35 per cent. of a tannin somewhat resembling that of oak-bark, but giving a browner colour and heavier bloom. It makes a hard and heavy leather, and is generally used in admixture with oak-bark, myrobalans, or mimosa-bark.

The Greek crop in 1880 was much damaged by the cold spring: it gave 600 tons in Acarnania and Ætolia, 650 in Cape Papa, and 1400 in Mania; total, 2650 tons. Calamata and Messenia produced 115 tons, 1700*l.* Syra exported in 1879, 1174*l.* worth to Great Britain, 348*l.* Austria, 259*l.* Russia, 250*l.* Turkey, 178*l.* Egypt. Hungary exported 942 tons in 1880. Adana shipped 9450*l.* worth in 1878; and Dedeagatch, in the same year, 1,500,000 lb., 9000*l.* Musyna [Mersineh] sent 670 tons, 3350*l.*, to Italy, and 450 tons, 2250*l.*, to Austria, in 1879; and 480 tons, 2240*l.*, to Italy, and 128 tons, 640*l.*, to Greece, in 1880. Our imports in 1880 were:—From Turkey, 30,391 tons, 471,637*l.*; Greece, 2916 tons, 41,312*l.*; other countries, 466 tons, 7105*l.*; total, 33,773 tons, 520,054*l.* The approximate London market values are:—Smyrna, 12*s.* 6*d.*–20*s.* 6*d.* a cwt.; Camata, 15–19*s.*; Morea, 10*s.* 6*d.*–18*s.*

Miscellaneous.—Besides the foregoing tannins, which already occupy prominent places in European and American commerce, there are many others as yet of minor importance, but possessing qualities which may bring them into note in the near future. They are as follows:—

Abies Larix bark, the larch, contains 6–8 per cent. of a red tannin.

Acacia albicans fruits, the *hiusache* of Mexico, are used as substitutes for gall-nuts, costing locally about 5*d.* a lb. *A. arabica*, the *babul* of India, yields a tannin which gives a nearly pure-white precipitate with gelatine: the proportions are 12·55 per cent. in trunk-bark, 18·95 in branch-bark, 15·45 in twig-bark. The supply is unlimited. It works well with myrobalans. *A. Cebil*, the red cebil of the Argentine Republic, contains 10–15 per cent. of tannin in the bark, and 6–7 per cent. in the leaves; another variety, the white cebil, contains 8–12 per cent. in the bark, and 7–8 per cent. in the leaves. *A. Cavenia*, the *espinillo* of the Argentine Republic, has 33–4 per cent. of tannin in the fruit-husks. *A. penninervis* bark, the "hardy" acacia of Australia, contains 18 per cent. of tannic acid and 3–4 of gallic.

Alnus glutinosa bark, the common alder, contains about 16 per cent. of tannin.

Cæsalpinia Cacalaco fruits, the *cascalote* of Mexico, are very rich in tannic and gallic acids, and locally used for tanning.

Comptonia asplenifolia leaves, the sweet-fern of the United States, contain 9–10 per cent. of tannin.

Coriaria ruscifolia bark, the *tutu* of New Zealand, contains 16–17 per cent. of tannin.

Elæocarpus dentatus bark, the *kiri-hinau* of New Zealand, contains 21–22 per cent. of tannin. *E. Hookerianus* bark, the *pokako* of New Zealand, contains 9–10 per cent. of tannin.

Ephedra antisyphilitica, on the table-lands of Arizona and Utah, gives 11–12 per cent. of tannin.

Eucalyptus longifolia bark, the "woolly-butt" of Australia, contains 8·3 per cent. of tannic acid and 2·8 of gallic. The "peppermint" tree contains 20 per cent. of tannic acid in its bark. The "stringy-bark" (*E. obliqua*) gives 13½ per cent. of kinotannic acid. The Victorian "iron-bark" (*E. leucoxylon*) contains 22 per cent. of kinotannic acid, but is available only for inferior leather.

Eugenia Maire bark, the *whawhako* of New Zealand, contains 16–17 per cent. of tannin. *E. Smithii* bark, the "myrtle"-tree of Australia, contains 17 per cent. of tannic acid and 3–4 of gallic.

Fuchsia macrostemma root-bark is thin, brittle, and easily exhausted; it contains about 25 per cent. of a bright-red tannin, which has been successfully tried. It is the *churco* bark of Chili, which, however, is attributed by the Kew authorities to *Oxalis gigantea*.

Inga Feuillei pods, the *pay-pay* of Peru, contain 24 per cent. of an almost colourless tannin.

Laurus Peumo rind is used in Chili for tanning uppers.

Malpighia punicifolia bark, the *naucite*, or *manquitta* bark of Nicaragua, contains 20–30 per cent. of a very light-coloured tannin.

Persea Lingue bark is red-brown, soft, and easily exhausted by water; it contains 20–24 per cent. of tannin, and much slimy matter which promotes the swelling of the hides. It serves in S. America, especially in the Chilian province of Valdivia, for tanning Valdivia leather. In S. Chili, are enormous forests of the tree. The imported bark has given good results with heavy leathers.

Phyllocladus tricomanoides bark, the *kiri-toa-toa* of New Zealand, contains 23 per cent. of tannin.

Polygonum amphibium leaves, an annual plant abundant in the Missouri Valley, contain 18 per cent. of tannin, and can be mown and stacked like hay. It is largely used in Chicago tanneries, and said to give a leather which is tougher, more durable, of finer texture, and capable of higher polish, than that tanned with oak-bark.

Punica Granatum fruit-rind, the pomegranate, contains about 13·6 per cent. of a tannin like myrobalans, and a considerable quantity of starch; the tannin is greatest in the bitter kind, which is used for preparing morocco-leather; the root-bark also is rich in tannin.

Rhizophora Mangle bark, the mangrove, of Venezuela, contains 24–30 per cent. of deep-red tannin, if obtained from young stems; samples from the W. Indies have given 11·94 per cent., probably by the gelatine process; two samples from Shanghai, by Löwenthal's improved method, gave respectively 9·8 and 9·5 per cent. calculated as oak tannin, and 71·96 and 78·52 of woody fibre. Guayaquil exported 9328 cwt. of the bark to Peru in 1879.

Tecoma pentaphylla bark, the *roble colorado* of Venezuela, contains 27 per cent. of tannin, accompanied by a soluble orange-red colouring matter.

Wagatea spicata pods contain 15 per cent. of tannic acid. The plant, a scrambling shrub, is a native of the Concans.

Weinmannia racemosa bark, the *tawhero towai*, or *kamai* of New Zealand, contains 12–13 per cent. of tannin.

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(See Acid—Gallic; Leather).

TEA (Fr., *Thé*; Ger., *Thee*).

The term "tea" is widely and vaguely applied to many plants (see pp. 2010–1), but is properly restricted to the numerous varieties derived by cultivation from two species of *Thea*, the Chinese (*T. chinensis* [*Camellia Thea*]) and the Assamese (*T. assamica*). As a result of long cultivation and promiscuous planting, there is scarcely a tea-garden but what is mainly filled with hybrids of all degrees between these two species. The Assam plant is vastly superior to the Chinese, and should be selected in all cases for rational culture. The seed of all is the same in appearance, and cannot be distinguished. It ripens about one year after the flower has faded. When picked in the shells, it is sunned for ½ hour daily for 2–3 days, "shelled," and spread to dry within a building. It should be sown as soon as possible after shelling: if kept for 2–3 weeks, it is best in layers under dry earth; if for longer, thinly spread on the drying-floor. It travels well in bags ⅓ filled, or in layers between charcoal in boxes. Its formation reduces the leaf-crop, and should be limited to actual needs. It furnishes a valuable oil (see p. 1411), not to be confounded with the essential oil of the leaves (see p. 1431). About 30,000 seeds are contained in 1 *maund* (of 80 lb.), of which about ⅔ may be expected to grow.

Cultivation. *Sowing.*—Seed is sometimes sown in nurseries, where they can be well tended; but this is costly, and the plants lose 3 months' growth when put out. Nurseries may be dispensed with where cool weather and spring rains are certain, but not otherwise. Nursery-beds are made in the poorest soil of the plantation, where watering is convenient. Artificial shade is essential. The beds are generally lower than the paths, to accumulate moisture, but may need to be above in some cases. The soil is loosened only to a slight depth, and the seed is sown in drills 6 in. apart, and the seeds 2–3 in. apart, if good. In the preparation of the ground, erection of shade, and general operations, there is little variation from the systems adopted with coffee (see pp. 691–8). The shade is removed gradually and piecemeal when the seedlings bear 4 leaves.

When nurseries are dispensed with, the seed is sown where the bushes are intended to remain (called sowing "at stake"). About 4 weeks previously, holes are dug 9 in. diam. and 12 in. deep, the soil being placed where it will not fall back; and these holes are filled up with surface soil (not that dug from them), with perhaps a handful of manure if the land is poor, and well pressed down for the reception of the seed. Two or three seeds are sown in this 6 in. apart, and gently pushed down about 1 in. The ground is then kept clean by hand-weeding, and lightened up at intervals by a *koorpee*. The best plant is left at each hole, the others being taken up and transplanted to vacancies.

Col. Money advocates another method of planting. The seed is put in layers alternating with mould, the seeds lying close together, and the earth covering them 2 in. deep. Each layer is examined every 3–4 days, and seeds which have burst are planted out root-side downwards. Only one seed need then be placed in each hole, as it is sure to grow; but great care is demanded in performing the operation.

Soil and Situation.—Tea grows on almost all soils, and flourishes on many. A light sandy loam is about the best, and the more humus there is on the surface the better; if 3 ft. deep, it matters little what the subsoil is, otherwise a mixture of sand and clay is desirable. Col. Money considers the light loam of Kumaon the best tea-soil in the world, being enriched with long accumulations of oak-leaves. Soil cannot be too rich for tea growing, provided it is sufficiently light and friable; the latter condition is absolutely essential, to permit the penetration of the spongioles (ends of the feeding-roots). Existing vegetation forms a pretty fair index of the fertility of the soil. Oak-bearing land is preferable to all others; but the removal of heavy forests adds much to the cost of taking in new land. Facilities for obtaining an abundant water-supply are quite indispensable; and the presence of means of water-carriage for conveying the crop to market materially adds to the advantages of the estate. Flat land is preferable to steep slopes; but the lower parts of slopes which are covered with jungle above are admirably adapted, as the vegetation diminishes the wash, and contributes rich fertilizing matters. Table-land cannot be too flat, but perfectly flat valleys are not eligible. Very narrow valleys are objectionable on all scores, and preference should be given to those which have a slope two ways. An adjacent stream for irrigation purposes is a great desideratum. Flat land always yields more heavily than slopes, as it admits of high cultivation. When planting on slopes, aspect is a primary consideration; it should be carefully chosen with a view of counteracting the extremes of climate: thus the coldest aspect will be the best in very hot climates, and *vice versâ*.

Forming a Tea-garden.—The first step will usually be to cut and burn the jungle, much in the same way as already described for coffee (see p. 692), a few large trees being left here and there (say 1 on every 2–3 acres) for sheltering the workmen, and shading picked leaf before it goes into house. Lining and holing are performed as in the case of coffee (see p. 693), the holes being 10 in. diam. and 15 in. deep. A garden of 100 acres is usually quite large enough to commence with. This should be divided into plots of 5–10 acres each, by means of paths or prominent stakes, the main object in view being to make separate sections for each portion of the crop that manifests any peculiarity in the number of its "flushes" or the quality of its leaves, many advantages arising from treating the crop in a piecemeal fashion, as the forwardness or backwardness of any section may require. Close planting is recommended by the best authorities, say 4–4½ ft. apart each way on flat ground, and 3½ ft. between the lines and 2 ft. apart in the lines when on slopes, to prevent wash. Close planting gives a greater number of bushes per acre, and keeps down weeds; but sufficient space must be left for digging between the bushes and picking the crop. Col. Money gives the following useful table showing the number of plants per acre, and the area covered by one lakh of seedlings, at the distances named:

Distances in ft.	Sq. ft. to each plant.	Plants in 1 acre.	Area in acres covered by 1 lakh of seedlings.	REMARKS.
6 by 6	36	1,210	82½	Too wide for any plants.
6 „ 5	30	1,452	69	
6½ „ 4	26	1,675	59¾	
5 „ 5	25	1,742	57½	
6 „ 4	24	1,815	55	
6 „ 3½	21	2,074	48	For hybrids, but still rather too wide.
5 „ 4	20	2,178	45½	
6 „ 3	18	2,420	41¼	Good distances for hybrids.
4 „ 4	16	2,722	36¾	
5 „ 3	15	2,904	34½	
4 „ 3	12	3,630	27½	Chinese, for early return.
3½ „ 3½	12¼	3,555	28	Chinese.
3½ „ 3	10½	4,148	24	
6 „ 3¼	19½	2,233	44¾	Hybrid.
5 „ 3¼	16¼	2,726	36¾	Chinese.
5 „ 3½	17½	2,489	40	
3½ „ 2	7	6,223	16	Best distance for Chinese on steep slopes.

On flat land, he advises—hybrid, if high-class, 4 × 3½ or 4½ × 4; Chinese, 3 × 3.

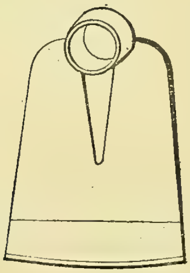
Planting.—About a fortnight before setting out the seedlings, they are "tipped" by pinching off the closed leaf at the head (see Fig. 1430), which makes them hardier. The removal of the seedlings is much facilitated by flooding the bed with water, as described for cinchona (p. 803), and similar care should be taken to have a good mass of soil around the roots. A good plan in taking up is to cut a trench below the bed, and then turn over line after line of seedlings by inserting a prong behind. The plants are carried in baskets to the garden, and there placed in little holes made with the hand or a narrow *kodalee* within the soft soil which has previously (p. 1994) been filled into the pit. The planting must be done so that the tap-root shall not turn up, that the rootlets shall preserve their lateral position, that the "collar" of the plant (where it issued from the ground in the nursery) shall be 1½ in. higher than the surrounding surface, and with so much pressure that the soil shall not cake about the plant, and shall be equally close at all depths. Cloudy and rainy days are the best for transplanting, but very wet weather is highly objectionable. In India, the operation is best performed by mid-June, and should not in any case extend beyond the end of July. Jeben has recently introduced some new tools for transporting and transplanting, which are highly approved of.

Cultivating and Pruning.—The soil overlying the roots of each plant should be repeatedly lightened up for the admission of air. This is best done by digging round the bushes with the *kodalee*, beginning at about 9 in. from the stem, and extending 2 ft. in all directions after the second year, taking care to use the blade of the tool so that it follows the line of the roots. A wide hoe is perhaps as useful a tool for this purpose. Till the plants are 1 year old, the soil for 6 in. round is only opened up about once a month with the *koorpee*. Weeds must be rigorously kept down, which is best done with a Dutch hoe. The weeds may be buried in trenches between the lines.

As it is only young wood and shoots that give leaf, pruning is essential to produce large crops. It must be done while the sap is down, and should be as soon as possible after the sap has gone down. It can only be performed in a rough and ready way, as the time is limited and the number of bushes to be treated is very great. Pruning-knives and hedge-bills, such as supplied by Brooker, Dore, & Co., London, are the best instruments. The same care in pruning the large branches must be exercised as with all other plants: the cut must be clean, sloping upwards, and not near enough to a bud to injure it. Such care cannot be taken with the numerous twigs. The plant should be induced to grow laterally, but not to exceed 4 ft. high. All branches less than 6 in. above ground should be pulled off downwards with a sharp tug. The centre of the bush must be opened out. No plant should be pruned for 18 months after transplanting, or the tap-root will not descend sufficiently. After that, all must be pruned, but some more than others. Two-year old plants over 2½ ft. high may be reduced to 20 in., and their thick wood to 11–18 in. It is better to prune too much than too little. The prunings are buried while green between the lines, and form good manure.

Other tools supplied by Brooker, Dore, & Co., to Indian tea estates are the solid *kodalee* (Fig. 1427), the cast-steel wedge-axe weighing 3 lb. and upwards (Fig. 1428), and the steeled Assam fork, with either 3 or 4 tines, weighing 4–5½ lb. (Fig. 1429).

1427.



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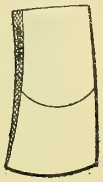

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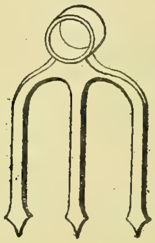


Filling-up Vacancies.—Filling up the vacancies left by the failing of some plants is usually a hopeless undertaking in the case of tea, as the young seedlings get destroyed by the weeding, and are starved out by the surrounding mature plants, consequently Indian tea-gardens have 12–40 per cent. of their area wasted by vacancies. Jeben's transplanter may perhaps succeed in overcoming the difficulties encountered. Meantime Money recommends a plan of planting in pots and staking the young plants, which has answered well. Earthenware pots 7½ in. diam. and 7½ in. deep, with a 2-in. hole in the bottom, are filled with soil from the garden; 2 or 3 seeds are put into each near the centre and ½ in. below the surface; and the pots are placed near water and under artificial shade. When germinated, the best seedling is left in the pot to grow till the rains, being watered occasionally, and gradually deprived of shade. After the first rain, the pot is removed to a hole prepared at the vacancy; the bottom of the pot is knocked off, the sides are broken and partially removed, and the whole is planted and earth is filled in round. With care, the rootlets are not disturbed, and the growth is not checked for a day. Bamboo baskets do not give such good results. Money proposes to modify this plan so as to avoid destruction of the pots, as follows:—The pots are made larger, and provided with a tin lining about 1 in. less in diameter, the intervening space being filled with sand; the tin lining is then removed, and the layer of sand permits the subsequent extraction of the plant with mould caked around it without breaking the pot, which may thus be used indefinitely. A somewhat similar plan is adopted with cinchona (see p. 802).

Manures.—Judicious manuring nearly doubles the yield of tea, and at the same time improves its flavour and increases its strength. An excellent manure available on all tea-gardens consists of the prunings of the bushes themselves, and the weeds and general garden rubbish. Of animal manures, the best are nightsoil and bird-droppings, and the next best is cattle-manure; horse-dung is heating, and needs to be used with care. Artificial chemical manures will probably come into extensive demand, as they have done for coffee, sugar, and other tropical crops. One highly spoken of is known as Money and Ponder's, and is manufactured by J. Thompson, Kooshtea, Bengal.

Manure should be applied to each bush, by laying it in a trench 9 in. wide and 6 in. deep, dug all round the bush at a distance of 6–12 in. from the stem, according to age, and covering it over with earth. Where there is not sufficient for this plan, it may be put into trenches between the lines, so that it will be accessible to the feeding-rootlets. The quantity of cattle-manure suitable for 4-year old bushes is 1 *maund* (of 80 lb.) for each 10–20 bushes, decreasing for younger plants.

Diseases and Enemies. Crickets.—These insects attack only young seedlings, whether in the nurseries or in the fields, about 2–3 in. high, cutting through the stem, and carrying away the leafy top to their holes. They seem to be most destructive on low lands, but their ravages cease when the stem of the plant is as thick as a stout pencil. The only remedy is to set boys to work to find their holes, and unearth the insects, paying according to the number brought in.

Ants.—White ants are a much more formidable pest, as they work in myriads, and attack even the largest bushes. Fortunately they have a deadly enemy in the black ant, but other precautions are necessary against them. Between the rains and the setting-in of the cold weather they most frequent the bushes, which latter should be examined for them in the autumn and the spring, and well shaken to effect their dislodgment. The best application to drive them away is petroleum, the refined kinds being more effective but more expensive than the crude. It may be sprinkled after diluting with water, or simply painted in rings around the stems and on the infected spots. Water impregnated with tobacco or tobacco-oil is less permanent in its efficacy.

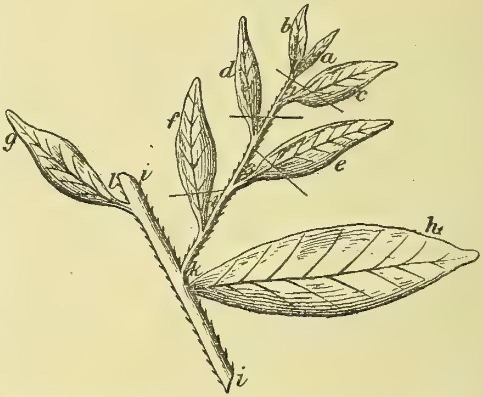
Blight.—This is most detrimental to the yield of a garden, as the young leaves become covered with brown spots, and shrivel up. Money recommends pruning off the diseased branches, and admitting air to the roots by scraping back the soil for 2 ft. round the stem, till the roots are nearly bared.

Flushes and Picking.—A "flush" of the tea-plant is when it throws out new shoots and leaves, the latter constituting the tea of commerce; thus the return from a tea-garden is governed by the number and extent of the flushes per season. These again depend upon the climate, soil, pruning, and cultivation; they may be said generally to range between 25 (in good soil and climate, with high cultivation and plenty of manure), to 18 (where no manure is used, and the cultivation is not high). The average flushing-period is 7–9 months, except for very elevated gardens, when the climate reduces it. Thus, in moderately high situations, it may last from early April to late October, giving 12–15, perhaps 18, flushes; in Upper Assam, Feb. 25 to Nov. 15; Lower Assam, Feb. 20 to Nov. 20; Cachar, Feb. 20 to Nov. 20; Chittagong, Mar. 10 to Dec. 20; Terai below Darjeeling, and W. Dooars, Mar. 1 to Nov. 20. These dates are fixed upon by Money, who considers that 25 flushes should be got within the periods stated. The average intervals between the flushes are approximately 7–14 days, varying with circumstances, and including abnormally long breaks which are sometimes caused by untoward weather.

Fig. 1430 illustrates the way in which the successive flushes occur, and the system of picking recommended by the best authorities. The harder a tea-bush is picked, within certain limits, the greater effort it will make to renew the leaves thus lost, and the greater the yield of leaves to be picked. The ordinary plant at the end of the season measures 3½–4 ft. high and 5 ft. diam., and is then pruned down to 2 ft. high and 3 ft. diam.; thus it remains during hybernation. In the spring, the buds at the bases of all the leaves, and which are the germs of future branches, gradually develop into shoots having 5 or 6 leaves with a closed bud at top. At the bases of these leaves are other buds, which similarly develop in time. The fully developed shoot has 6 leaves, including the bud, marked *a b c d e f;* it has started from a bud *k* at the base of the leaf *h*, and now forms a complete "flush." The leaves *a b*, &c. have also buds 1 2 3 4, which will likewise develop in turn.

Assuming the shoot *k* to be the first on the branch *i*, it forms the basis of future crops on that part of the bush, and must not be removed. But its tendency to throw out new shoots is much increased by nipping off the bud *a*, in such a manner as not to injure the bud at the base of *b*. The lines indicate the points at which the leaves are nipped so as to avoid hurting the buds. The leaves *a b* are covered with a white silky down, and make a white or very pale yellow tea (not infusion), which, mixed with ordinary tea, constitutes "Pekoe tips," and adds much to the value. With the advance of the crop, it is practically impossible, by reason of the great cost for labour, to pick the various kinds separately: but in the first 2 or three flushes, no more than *a* and *b* ought to be picked, and they will then make a small quantity of white Pekoe tips. Later on, the colour becomes orange.

1430.



The value of the leaves depends on their succulence, which is coincident with their youth. The youngest leaf makes the best tea, and the order of merit is:—*a* gives Flowery Pekoe; *b*, Orange Pekoe; *c*, Pekoe; *d*, First Souchong; *e*, Second Souchong; *f*, Congou; *a b c* mixed, Pekoe; *a b c d e* mixed, Pekoe Souchong; if there were a leaf picked below *f* it would make Bohea. The best cultivators do not take any leaf below *e*. The succulent stalk down to the line marked 2 also forms good tea. It would be a great advantage to the product if each leaf could be separately picked and manufactured, so as to modify the treatment according to requirement, but the labour entailed is enormously costly, and the universal practice is to pick and manufacture all indiscriminately, trusting to the final sifting and sorting process (p. 2002) to separate the various kinds with more or less precision.

Money recommends the following plan in picking. If the garden has been pruned as it ought to be, take only *a* for 2 flushes; for 2 more, nip the stalk above 1, taking the upper part of *c*, as shown; from the 5th flush, take off the shoot at the line above 2, and by a separate motion of the fingers take off at *e* at the line. By this plan, when the rains begin, the trees will show a large picking surface, for plenty of buds will have been preserved for new growth. After August, pick lower if desired, as the trees cannot be hurt: for instance, nip the stalk and upper part of *e* together, and separately the upper part of *f*. The principle of picking is to leave intact the bud at the axis of the leaf down to which picking is carried. Some planters pick all through the season at the line above 1, and take *d* and perhaps *e* separately. This plan will make strong teas, but the yield will be small; the plants will also form so much foliage that they will not flush well, and will grow so high that the boy pickers will not reach the top. The principle advocated by Money is to prune severely, so that the plant shall throw out many new shoots; to be sparing with these until the violence done to the tree is in a measure repaired; till September, to pick so hard that the wants of the plant in foliage are never quite attained; and after September, to take all that can be got.

MANUFACTURE.—The aim of the manufacturer should be to produce those qualities which are sought after by the buyer. Brokers judge of tea by the tea itself, the infusion or "liquor," and the spent leaves or "out-turn." The tea should be of uniform greyish-black with a gloss on it; it should be regular in length and twist, and all of one kind. The liquor should have a strong, rasping, pungent flavour; there are many special sub-flavours which cannot be described. The out-turn should be uniformly of the colour of a bright new penny, with greenish rather than black leaves interspersed. Every parcel of tea should be infused and tasted as made, and binned with great care according to its quality. The one difficulty in tea-making is to get Pekoe tips in all Pekoe teas. If the leaves giving tips are separately manufactured,—rolled very little and lightly, not fermented at all, sunned after rolling, and finished in the sun or above the drawers in the *dhole*-house,—they will give perfect white tips; but if mixed with the other leaves, they absorb juice from them in the rolling, and become all black alike. In some instances, it will pay to separate the *a* and *b* leaves by hand; machines invented with that object will be described in due order.

The several processes to which tea is subjected are withering, rolling, fermenting, sunning, and firing or dholing.

Withering.—Withering is effected by a combination of light, heat, and air, best attained by spreading in the sun, when the weather is favourable. Failing this, withering in pans and *dholes* may be resorted to, but always renders the out-turn more or less green. It is better spread on bamboo *mechans* placed in every available sheltered and ventilated space, and on wire-mesh frames suspended so as to draw up under the roofs of the buildings. Ventilated houses of iron and glass have also been built for this purpose. But artificial withering is always inferior to the action of the sun. In dry weather, the leaf as brought in should be spread thinly anywhere that is convenient, and turned once in the night; if not ready for rolling next morning, ½ hour in the sun will generally complete the withering. In unsettled weather, every hour of chance sunshine should be availed of. The tests for properly withered leaf are that it gives no crackling sound on being crushed in the hand, retains the shape to which it is compressed, feels like old rags, and the stalks bend without breaking. Men put in charge of the withering operations should be kept to that alone, and the same rule should be adopted with the other processes.

Rolling.—Some planters advocate circular rolling; some roll the leaf forward, but bring it back without letting it turn; the ordinary forward and backward motion is the simplest and quickest, and that which rollers adopt when given a certain quantity (say 30 lb.) of leaf to roll for a day's work. Rolling in hot pans, formerly extensively practised, is not much done now, and has no advantage. Rolling on coarse mats placed on the floor is a great mistake, as the coarse bamboo mat breaks the leaf, and much of the juice from the leaf, which adds to the strength of the tea, runs through and is lost.

A smooth rigid table 4½ ft. wide, with planks well joined so that no apertures exist for the juice to run through, is best to roll on, especially if covered with a fine *seetul-pattie* mat, nailed down over the edges. A border of wood 1 in. above the surface of the table is screwed on to the edges over the mat, to prevent leaf falling off. The leaf is rolled by a line of men on each side, who pass it up one by one from the bottom of the table to the top. The passage of each handful of roll is regulated by the man at the end, who, when it is rolled enough, forms it into a tightly compressed ball, and puts it on an adjacent stand. The roll is ready to make into ball when it is soft and "mashy," and when it gives out juice freely. This juice is mopped up into the roll, again and again in its passage up the table, and finally into the ball when made up.

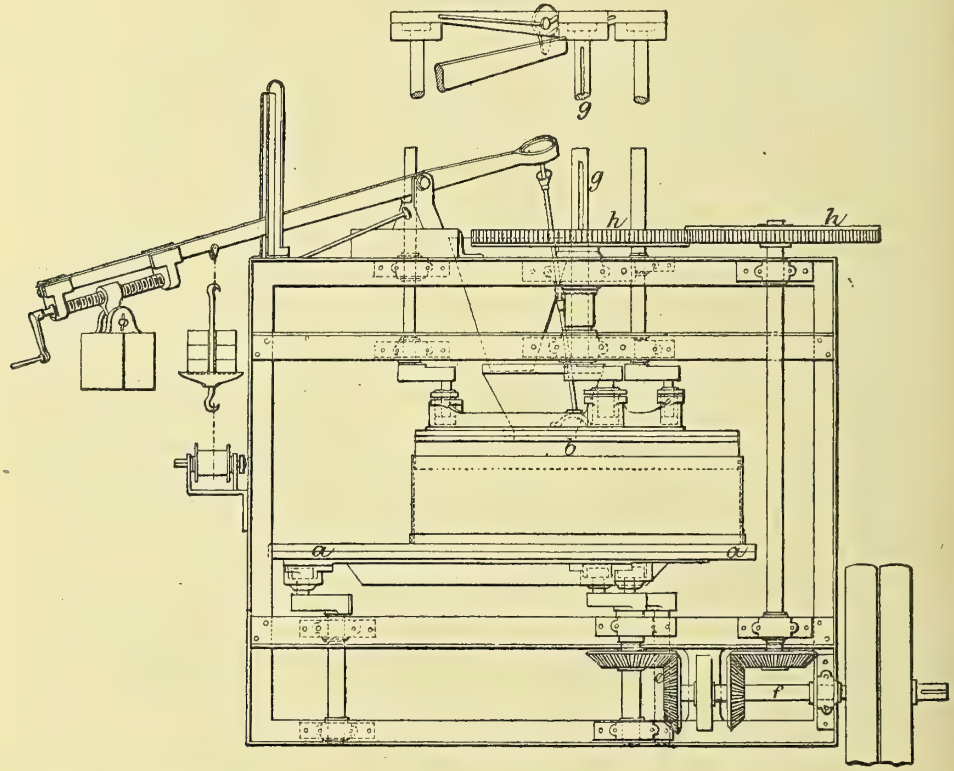
Coarse leaves in the roll cannot be twisted, and if left would give much red leaf in the tea. They should be picked out by the 3rd or 4th man from the head of the table, who should not have to roll at all. He spreads the roll and picks out as much as he can between the time of receiving and passing it on, in no case allowing roll to accumulate by him, or it hardens and dries, and gives extra work to bring it into a mashy state again, besides helping to destroy Pekoe ends, and being injurious to the after-fermentation.

Many apparatus and machines have been invented for rolling tea, mainly with the object of reducing the labour, and increasing the proportion of Pekoe tips.

McMeekin's rolling-table is constructed of battens, so that while rolling, many of the small leaves (Pekoe tips) fall through. This table is well known in Cachar, and used in several gardens, but the objection to it is that the leaf must be rolled lightly, and such leaf cannot make strong tea. Pekoe tips may be in a great measure preserved by rolling all the leaf lightly on a common table, but this plan will not give so many Pekoe tips as McMeekin's table. Planters still feel the want of a machine to separate quickly and cheaply the two said small leaves from the others after they have been picked together. All the other processes can be done cheaply by hand, but this cannot.

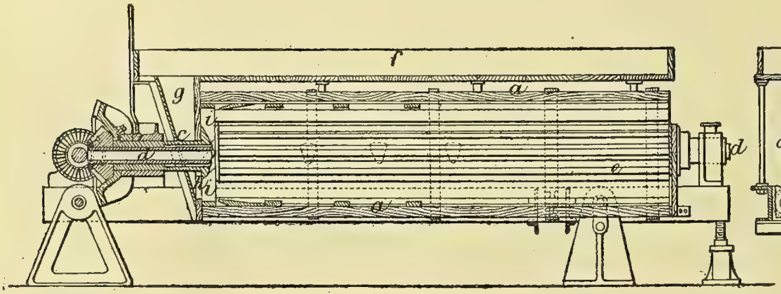
Kinmond's rolling-machine consists of two circular wooden discs, the upper one moving eccentrically on the lower, which is stationary. The adjacent faces of the discs are made rough by steps in the wood, cut in lines diverging from the centre to the circumference, and over these rough faces is nailed coarse canvas. The leaf is placed between the discs and rolled by the motion described, the lower disc being arranged by weights and pulleys, to press against the upper with any force desired. The motive power may be animal, water, wind, or steam. The machine is shown in Fig. 1431. The rolling of the leaves is effected between superposed horizontal plates, *a b*, the opposite faces of which are recessed to a depth of 3–4 in., these recesses being corrugated to aid the rolling and prevent the leaves from slipping. The under plate *a* is mounted upon 3 strong cranks arranged equidistantly in a triangle; the shafts supporting them are carried by exterior plummer-blocks, one having a revolving motion imparted to it by bevel-gearing *e* from a driving-shaft *f*, carried also by exterior plummer-blocks, and provided with fast and loose pulleys. The plate *a* thus receives a horizontal circular traversing motion, but it has no rotating motion around its own axis, neither has it a rising-and-falling motion. The upper plate *b* is similarly suspended from cranks connected by a triangular frame, the shaft *g* having a revolving motion imparted to it by spur- and bevel-gearing *h* from the shaft *f*. The various levers and weights shown are for the purpose of raising the upper plate for the tea to be fed in, and to enable the pressure to be adjusted according to requirement.

1431.

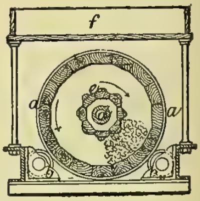


Jackson's rolling-machine is an improvement upon Kinmond's, but is declared to be an infringement of the latter. It is shown in Figs. 1432, 1433. *a* is a cylinder composed of teak staves, with an uneven internal surface, mounted so as to be capable of rotation, supported at one end on rollers *b*, on the main frame of the machine, and at the opposite end upon a sleeve *c*, supported in a bearing on the frame. Through the sleeve passes a central shaft *d*, bearing at the opposite end on the main frame This shaft carries a roller *e*, having an uneven external surface, and of such dimensions that an annular space is left between it and the cylinder *a*. Rotary motion is imparted in opposite directions, as indicated by the arrows, the roller receiving the greater speed. A supply of tea-leaf is

1432.



1433.



introduced into the feeding-trough *f*, whence it passes down a hopper *g*, and through an opening *h*, in the non-rotating end of the cylinder *a*.

No rolling-machine, probably, will supersede entirely the necessity of hand-rolling: a machine is very useful to roll the leaves partly, to break the cells, and bring the leaf into a soft, mashy state, so that very little hand-labour will finish it; but machines do not give the nice final twist which is obtained by the hand. By employing both, very few rolling-men suffice to manufacture a large quantity of leaf.

Nelson's rolling-machine does not profess to do more than prepare the green leaf for rolling. The leaf is placed in bags, and compressed under rollers attached to a box weighted with stones. The inventor states that it will prepare 80 lb. of green leaf in 15 minutes, and that one man can then finish as much prepared leaf in 3 minutes as would otherwise occupy him 12 minutes. The machine is inferior to Kinmond's in arrangement, and ought to be very cheap, as it is simply a mangle.

Fermenting.—The balls accumulated by the rolling-men are allowed to stand until fermented, which is, perhaps, the most important point in the whole manufacture. Some planters collect the roll in a basket, and let it ferment there instead of in balls. But when a quantity is put into a basket and allowed to ferment a certain time, the first part is more fermented than the last; while balls can be taken in the order in which they were laid on the table, and thus each will receive the same amount of fermentation. Further, the twist is better preserved by the balls, and a large quantity in a basket is apt to ferment too much in the centre. It is impossible to describe with useful accuracy when the balls are sufficiently fermented. The outside is no criterion, as it varies much, according to the degree of withering. The more the leaf is withered, the thicker in consistency and the smaller in quantity is the juice that exudes, as also the yellower in colour; further, the darker is the outside of the balls. Bright rusty-red is the colour of moderately-withered leaf; very dark greenish-red when much withered. A good rule is that half the twisted leaves inside shall be rusty-red, half green; but practice alone can guide. The process is quicker in warm than cool weather, but requires no fixed time. It should be stopped in each ball just at the right moment by breaking up the ball, and spreading it out very thin; at the same time any remaining coarse leaves are picked out.

Sunning.—The fermented roll is immediately spread very thin on *dhallas* or mats in the sun. When become blackish in colour, it is collected and re-spread, so that the whole shall be equally affected. In bright sunshine, an hour or less suffices; it is then placed at once in the *dholes*, previously got ready to receive it. In wet weather, directly the balls are broken up, and the coarse leaf is picked out, the tea is sent to the *dholes*; but the best tea is made in fine weather.

Firing or Dholing.—The least delay between breaking up the balls and beginning to drive off the moisture is injurious. In wet weather, unless there are many *dholes*, time will not permit each roll to be finished. The only plan then is to half-fire them, to avoid injury by delay; but in any other case, the roll should not be removed from the drawer until it has become tea. The roll in each drawer is shaken up and respread 2 or 3 times during the firing. The rolls remain in the drawers under the influence of the heat of the burning charcoal till it is quite dry and crisp, and thoroughly brittle.

By the old plan of firing, a single wicker sieve was inserted in a bamboo frame called a *dhole*, placed over a charcoal fire in a hole in the ground. Several inventors have improved upon this crude and wasteful method. McMeekin's chest of firing-drawers, now generally used, consists of a system of drawers or trays fitted in a frame one above another, the bottom of each tray being made of fine iron wire, so that the heat of the charcoal, in the masonry receptacle over which it is placed, ascends through all the drawers, and "fires" or dries a large quantity of "roll" at the same time. The economy of fuel is great, but Money thinks that with 4 or 5 superimposed drawers, the steam ascending from the lower ones must more or less injure the roll above; he confines himself to two, and in the top tray leaves a small circular space by which the steam from the lower drawer can escape. The escaping heat is partially utilized by placing *dhallas* in tiers above, with roll in them, supported by iron rods let into the wall; they are useful for partly drying roll, and for withering leaf when there is no sun.

Some planters have proposed to do away with charcoal under McMeekin's drawers, supplying its place by hot air. It was long supposed that the fumes of charcoal were absolutely necessary to make good tea. Col. Money has disproved this by making as good or better tea without charcoal, and drying chambers using hot air generated in outside furnaces are coming into favour. The advantages are:—(1) The economy of $\frac{6}{7}$ of the fuel used; (2) cleanliness and absence of charcoal-dust; (3) absence of the objectionable carbonic acid fumes of charcoal; (4) immunity from fire; (5) greater speed in the firing process, and saving of all the labour employed to make charcoal; (6) reduced temperature in the tea-houses.

Green Tea.—For green tea, the leaf is brought in twice daily: that coming in at 1 P.M. is partly made the same day; that brought in at evening is spread 6 in. thick till next morning. If either arrives wet, it must be dried, the former before going into the pans, the latter before being spread. The dry leaf is put into thick pans, 2 ft. 9 in. diam. and 11 in. deep, set sloping over fireplaces, and numbering 4 or 5 for every *maund* (80 lb.) of tea to be made per diem. The pans are heated to about 71° (160° F.), and the leaf is stirred for about 7 minutes with flat sticks, till it becomes moist and sticky. It is next rolled on a table till it gets a little twisted (say 2 or 3 minutes), and is laid out 2 in. thick on *dhallas* in the sun for 3 hours, being rolled three times in that period, for not more than 3 minutes each time, when it has become blackish on the surface; it is then spread out as before. After 3 rollings, it should have a good twist. It is replaced in the pans at the same heat, and worked with the stick till it is too hot to hold (say 2–3 minutes). Next it is stuffed as tightly as possible into bags 2 ft. long and 1 ft. broad, made of No. 3 canvas; the mouths are tied up, and the bags are beaten heavily to consolidate the contents, and thus left for the night. In the morning, the tea is turned out, and worked with the sticks in the pans at a temperature gradually falling from 71° (160° F.) to 49° (120° F.): the green colour is thereby produced. The leaves of the Chinese plant make the best green tea, while hybrids are best for black.

Sifting and Sorting.—These operations constitute a very important item in the manufacture, as they may make a difference of 2–3 annas a lb. in the selling-price of the tea. Tea-sieves are round, and either of brass wire with wooden sides 3½ in. high, or of cane with bamboo sides 1¼ in. high. The latter are Chinese, and superior in every way to the former. Both are numbered according to the orifices in 1 linear in., the brass numeration including the diam. of the wire, and thus giving a slightly less aperture than the corresponding number in cane sieves. Tea should be sifted daily, taking that made on the previous day, and be binned in that state. For daily sifting in an ordinary garden, the sieves (Chinese) required will be: 4 of No. 4, 6 of No. 6, 6 of No. 7, 9 of No. 9, 9 of No. 10, 6 of No. 12, 4 of No. 16. Red leaf is carefully picked out before commencing to sift. No rules can be laid down for sifting and sorting; much practice is required to make an efficient sifter, and no two batches of tea will demand precisely the same treatment. Hence the general failure of sifting-machines for this purpose, since they cannot be worked economically and at the same time adjusted to suit all needs; fanning-machines, however, may be used to separate dust and open leaves.

The classification of black tea is according to the size, make, and colour of the leaf, the ordinary descriptions being Flowery Pekoe, Orange Pekoe, Pekoe, Pekoe Souchong, Souchong, Congou, Bohea; and of broken kinds, Broken Pekoe, Pekoe Dust, Broken Mixed Tea, Broken Souchong, Broken Leaf, Fannings, and Dust.

Flowery Pekoe generally preserves a uniform greenish-grey or silver-grey tint. Its liquor is very strong, in flavour approaching green teas, but infinitely superior, having their strength and astringency without their bitterness; it is pale, and the infused leaf is of a uniform green hue. When too much heat has been employed, dark leaves are intermixed, and the prevailing green is sprinkled with leaves of a salmon-brown tinge, which is the proper colour for the out-turn of any other ordinary black tea. A common mistake is to call ordinary Pekoe containing an extra amount of Pekoe ends, Flowery Pekoe. When strong and of Flowery Pekoe flavour, it is called a Pekoe of Flowery Pekoe kind. In England, Flowery Pekoe is worth about 4*s.* 6*d.*–6*s.* 6*d.* a lb.

When the Pekoe ends are yellowish or orange, and the leaf is very small and even, the tea is called Orange Pekoe. In flavour, it is much the same as ordinary Pekoe, and many growers send away the two varieties in the finished state mixed together. Its value is 2–4*d.* a lb. more than Pekoe.

Ordinary Pekoe is of blackish or greyish-black aspect, dotted over with greyish or yellowish leaves possessing the downy appearance which gives the name to Pekoe. In general, the whole leaf is not covered with down, but only a part of it which has been developed late. These are called "Pekoe ends" when very small. Pekoe is generally of good to fine flavour, and very strong, and its liquor is dark. Its value is 2*s.* 9*d.*–3*s.* 8*d.* a lb.

The term Pekoe Souchong is generally applied to a Pekoe that is deficient in Pekoe ends, or to a bold Souchong leaf with a few ends mixed. It is often applied to an unassorted tea, including perhaps Souchong, Congou, a few Pekoe ends, and some broken leafs. Prices average 2*s.* 3*d.*–2*s.* 10*d.* a lb.

Broken Pekoe is Pekoe which has been broken in manipulation or otherwise. It possesses the strength and fine flavour of a full leaf of Pekoe, being therefore only inferior to it in point of leaf. In value, it is very little inferior to Pekoe, sometimes even superior, as the tender Pekoe ends are frequently broken off in large quantity, adding to the value of the broken tea, while deteriorating the Pekoe. Ordinary prices are 2*s.* 6*d.*–3*s.* 4*d.* a lb.

Pekoe Dust is broken so small as to resemble dust. It is of great strength, though often not pure in flavour, as frequently any dust or sweepings from other tea is mixed with it to make the lot larger. The price may range from 1*s.* 6*d.* to 2*s.* 8*d.* a lb.

Souchong may be taken as the medium quality, and, when experience and skilled labour are employed in the manufacture, as the bulk of the produce of an estate. The qualifications are an even, straight, or slightly curved leaf, ½–1½ in. long. It has not the deep strength of Pekoe, but is generally of good flavour and fair strength. Prices are 1*s.* 10*d.*–2*s.* 8*d.* a lb.

Congou may be either a leaf of Souchong kind, but too large to come under that class, or a smallish-sized leaf, too unevenly made, or too much curled. The flavour is much the same as that of Souchong, but the tea has less strength. Some of the lower and large-leaf kinds may be only worth 1*s.* 3*d.*–1*s.* 6*d.*, whereas finer qualities sell at 2*s.*–2*s.* 3*d.* a lb.

Bohea may be either of too large a leaf to be called Congou, or, as is generally the case, may consist principally of old leaf, which, on being fired, does not attain the greyish-black colour desirable in all black kinds except Flowery Pekoe, but remains of a brownish or pale-yellowish hue. It has scarcely any strength, is generally of coarse flavour, and is never of much value unless of Namuna kind. Prices are 3*d.*–1*s.* 2*d.* a lb.

Broken Mixed Tea is a mixture of the various kinds broken, and may include some of the lower classes, or approach Broken Pekoe in character and value; but it is usually worth 1*s.* 8*d.*–2*s.* 6*d.* a lb., and of a blackish aspect, containing a few Pekoe ends.

Broken Souchong is a tea, which, though broken, has some approach to a full leaf of the even Souchong character. Value, 1*s.* 6*d.*–2*s.* 2*d.* a lb.

Broken Leaf is a term of great comprehensiveness, but generally signifies a tea worth 8*d.*–1*s.* 1*d.* a lb., of brownish, brownish-black, or blackish colour. Its strength is seldom great; its flavour may be fair or good, but in the lower qualities is generally poor, thin, or coarse.

Fannings is similar in colour and class to broken leaf; in value it is also much the same, perhaps on the average a little lower.

Dust is very small broken tea. It is often very coarse or "earthy" in flavour, owing perhaps to sweepings and dust having become mixed with it. Its value is 6*d.*–1*s.* 6*d.* In any worth more than these quotations, a few Pekoe ends or tips will be found, bringing it under the name of Pekoe Dust.

Another class of tea possessing very great strength and very fine flavour is known as Namuna. The leaf may have perhaps the ordinary greyish-black aspect, with generally a greenish tinge. In the pot, it produces a very pale liquor, but its quality is stronger by far than ordinary Pekoe; in flavour, it is about half way between Flowery Pekoe and a green tea, quite distinct from Flowery Pekoe, possessing somewhat of the rasping bitterness of the green-tea class with the flavour a little refined. The out-turn is generally green, sometimes with brownish leaves mixed. Any black tea may be of this class, from Pekoe to the lowest dust, and all, if the flavour be distinct and pure, may have their value enhanced 4–10*d.* a lb.

Similar in all respects but one, is Oolong. The wanting quality is strength. Sometimes the flavour is a little different. It is generally composed of greyish-black leaves with a few green ones intermixed; it always has a pale liquor, generally a greenish infused leaf; but its flavour is frequently burnt out, though its weakness and green appearance are often caused by deficient firing. Teas of this kind on the average sell below the ordinary-flavoured teas of the same class of leaf.

In teas of ordinary flavour, the following rules hold good:—The darker the liquor, the stronger the tea; and the nearer the infused leaf approaches a uniform salmon-brown, the purer the flavour. Whenever black leaves are mixed with the out-turn, the tea has been over-fired, and the strength is either burnt out of it, or a burnt or smoky flavour is given. An altogether black or dirty-brown out-turn is certain to give pale liquor of little or no strength, and no flavour unless it be sour. This sourness is of various grades,—slightly sourish, sourish, and sour, depreciating the value 3*d.*–1*s.* 6*d.* a lb. The flavour is hardly capable of description. The least tendency to it condemns the parcel at once. The cause assigned for it is that the leaf after being picked is allowed to remain too long in the raw state before being fired, undergoing fermentation.

Burntness may either destroy the strength and flavour altogether, or, without destroying the strength, add an unpleasant burnt flavour, when the tea is called "smoky" or "smoky burnt," and deteriorated in value 2*d.*–1*s.* a lb. Symptoms of burntness are a dead-black leaf, having a burnt smell which often entirely neutralizes the natural aroma. The terms "fresh burnt," "brisk burnt," "malty burnt," are not condemnatory, and the word burnt, as used here, would be better expressed by fired. "Malty" means of full rich flavour. "Full," applied to a liquor, does not signify strength or flavour, but is opposed to thinness. A green tea may be strong or of good flavour, but its liquor is never full. Fulness is generally characterised by a dark liquor, and is akin to "body" in a wine. "Chaffy" is generally used for Bohea and other brown-leaf classes. A light, open, brown leaf would be called chaffy. The lower classes, especially dusts, are often described as "earthy" in flavour, perhaps caused by the admixture of real dirt.

When a tea is spoken of as "well made," "fairly made," &c., the manipulation is referred to. There are "straight" and "curled," or, as the latter is generally expressed when applied to large leaf, "twisted" leaves. It may be "flattish made," indicating that though the leaf is not open, it wears a flattish aspect, or it may be open, which betrays a want of sufficient or skilful manipulation.

A "wiry" leaf is small, perfectly rolled, and very thin (in diameter) generally rather curled, so as to resemble small pieces of bent wire. Only the finer teas can have a wiry leaf, principally the Orange Pekoes and Pekoes. Sometimes a fine Souchong may be thus described.

Of green teas, Gunpowder is the most valuable description, its price ranging from 2*s.* 8*d.* to 3*s.* 8*d.* a lb. Instead of possessing the long and thin finished leaf, which is the desideratum of black teas, it is rolled into little balls $\frac{1}{8}$–$\frac{1}{4}$ in. diam. Sometimes it has some long leaf mixed.

Tea of the shape of Gunpowder, but larger, is called Imperial. Prices are 10*d.*–2*s.* 6*d.* a lb.

Hyson may be taken as the parallel of Souchong in black-leaf descriptions. There is often much young Pekoe leaf in it, but all chance of discovering it in the finished leaf is precluded by the change in colour. Hysons sell at 1*s.* 2*d.*–3*s.* 6*d.* a lb.

Young Hyson is smaller than Hyson, occasionally slightly broken. It fetches 7*d.*–2*s.* 6*d.* a lb.

Hyson skin consists of bold broken Hyson and young Hyson. A small broken green tea is seldom sent on the home market. The reason is obvious: when Hyson skin only fetches 7*d.*–1*s.*, anything approaching dust would give very little chance of profit. It would be well if all planters would take a lesson from the Chinese, and not send home their very low teas, black or green, as they are very difficult of sale in London, and in many cases cannot pay the cost of packing and shipping. The Chinese make much of their broken teas into brick tea, and send it into Central Asia, where it meets with a ready sale. In the N.-W. Provinces, the natives are beginning to consume largely, and will pay 8 annas to 1 rupee for tea that would not fetch more than 1*s.*–1*s.* 6*d.* in England. Whether the natives of India, as a whole, do or do not take to drinking tea, will have a material effect on the future prospects of the industry. The manufacture of green teas is probably less remunerative than that of blacks, and there is far less demand for them in England, though considerable in America.

Caper is made in large quantity in China. It forms a link between the black and green descriptions. The colour of the leaf is a very dark green; in form, it is similar to a Gunpowder, Imperial, or round-leaf Congou; the liquor is pale, and the out-turn green; flavour, perhaps nearer to that of green than black tea.

Packing.—The best tea-boxes are of teak, made at Rangoon. The wood is sawn by machinery into pieces which will make each chest measure inside 23 × 18 × $18\frac{1}{2}$ in.; the contents are 7659 cub. in., sufficing for above 1 *maund* (80 lb.) of fine, and under 1 *maund* of coarse tea. Each box is composed of fourteen pieces, nailed together with "French pins," $1\frac{5}{8}$ in. long. It is extremely important that the tare of all the boxes shall not vary more than $\frac{1}{2}$ lb., or the whole will be turned out and reweighed in London. All the boxes are lined inside with a thin leaden shell.

Tea may be packed only on fine hot days. It is first "bulked," i. e. turned out on a cloth and mixed most intimately. It is also finally dried to remove the moisture imbibed during storage, even though kept in zinc-lined bins. Sun-drying is far best. The tea is put into the box while hot, first taking enough to $\frac{1}{4}$ fill the box. This is rocked till it is thoroughly settled, and then trodden down by a man standing on a piece of carpet; this is repeated with decreasing instalments, dispensing with the rocking for the last 2 or 3 additions. When full, a sheet of "silver" paper is laid on the tea to catch drops caused while soldering the top, which, with the nailing on the cover, is the final operation. To take the tare of the boxes, they are weighed with the leaden lining and leaden top; when filled and soldered, but before putting on the wooden top, they are again weighed for the gross. The tares must be equalized by adding nails, solder, or hoop-iron bands. The boxes are finally marked.

Cost of a Tea Garden.—Col. Money gives the following approximate estimate of the cost to establish a 300-acre tea-garden:—

1st year.	*Rs.*	
700 acres of land, at Rs. 8	5,600	(560*l.*)
40 *maunds* of seed, at Rs. 70	2,800	(280*l.*)
Nurseries for vacancies, and labour of transplanting	200	(20*l.*)
First temporary buildings	1,000	(100*l.*)
Cost of planting 100 acres, at Rs. 80	8,000	(800*l.*)
Cultivating 100 acres 1st year, at Rs. 50	5,000	(500*l.*)
	22,600	(2,260*l.*)

2nd year.		
60 *maunds* of seed, at Rs. 70	4,200	(420*l.*)
Nurseries, and labour of transplanting	300	(30*l.*)
Repairs and new buildings	500	(50*l.*)
Cost of planting 2nd 100 acres, at Rs. 70	7,000	(700*l.*)
Cultivating 1st 100 acres, at Rs. 60, and 2nd 100 acres, at Rs. 50	11,000	(1,100*l.*)
	23,000	(2,300*l.*)

3rd year.

	Rs.
70 *maunds* of seed, at Rs. 70	4,900 (490*l.*)
Nurseries, and labour of transplanting	400 (40*l.*)
Buildings for manufacture (temporary), and repairs	3,000 (300*l.*)
Cost of planting 3rd 100 acres, at Rs. 60	6,000 (600*l.*)
	14,300 (1,430*l.*)
Cultivating 1st 100 acres, at Rs. 70, 2nd at Rs. 60, and 3rd at Rs. 50	18,000 (1,800*l.*)
Interest on 1st year's outlay for 2½ years, 2nd year's for 1½ year, and 3rd year's for ½ year, at Rs. 5 per cent. per annum	5,357 (535*l.*)
Total cost of making 300-acre garden	83,257 (8,325*l.*)

4th year.

20 *maunds* of seed, at Rs. 70	1,400 (140*l.*)
Nurseries, and labour of transplanting	500 (50*l.*)
Repairs to buildings	500 (50*l.*)
Cultivating 1st 100 acres, at Rs. 80, 2nd at Rs. 70, and 3rd at Rs. 60	21,000 (2,100*l.*)
	23,400 (2,340*l.*)

5th year.

10 *maunds* of seed, at Rs. 70	700 (70*l.*)
Nurseries, and labour of transplanting	500 (50*l.*)
Repairs to buildings	500 (50*l.*)
Cultivating 1st 100 acres, at Rs. 90, 2nd at Rs. 80, and 3rd at Rs. 70	24,000 (2,400*l.*)
	25,700 (2,570*l.*)

6th year.

Nurseries, and labour of transplanting	500 (50*l.*)
Repairs to buildings	500 (50*l.*)
Cultivating 1st 100 acres, at Rs. 100, 2nd at Rs. 90, and 3rd at Rs. 80	27,000 (2,700*l.*)
	28,000 (2,800*l.*)

7th year.

Nurseries, and labour of transplanting	500 (50*l.*)
Building permanent factory and store, and repairs to buildings	12,500 (1,250*l.*)
Cultivating 1st 100 acres, at Rs. 100, 2nd at Rs. 100, and 3rd at Rs. 90	29,000 (2,900*l.*)
	42,000 (4,200*l.*)

8th year.

Nurseries, and labour of transplanting	500 (50*l.*)
New permanent houses for manager and assistant, and repairs to buildings	8,500 (850*l.*)
Cultivating 1st, 2nd, and 3rd 100 acres, at Rs. 100	30,000 (3,000*l.*)
	39,000 (3,900*l.*)

9th and all succeeding years.

Nurseries, at Rs. 500 Repairs to buildings, at Rs. 500	1,000 (100*l.*)
Cultivating 300 acres, at Rs. 100	30,000 (3,000*l.*)
	31,000 (3,100*l.*)

Cost of Manufacture.—The cost of manufacture, sorting, packing, freight, and brokerage, per *maund* (80 lb.) of tea is given by Money as follows:—

	R.	A.	P.	s.	d.
Manufacture.					
1 head man with the pickers	0	4	0	0	6
320 lb. green leaf picked, at 1 pie	5	0	0	10	0
1 man withering leaf, at 4 annas	0	4	0	0	6
¼ share head man in rolling-house	0	2	0	0	3
10⅔ men rolling, at 30 lb. leaf per man, and 4 annas per man	2	10	8	5	4
¼ boy clearing out ashes of *dhole*-house, at 2 annas	0	0	6	0	0¾
¼ share head man in *dhole*-house	0	2	0	0	3
1 man firing *dhole* work	0	4	0	0	6
¾ *maund* charcoal for *dhole* work, at 8 annas	0	6	0	0	9
Lights for night work, viz. turning green leaf and *dholing*, say	0	4	0	0	6
Wear and tear of *dhallas*, baskets, picking-baskets, fuel for artificial withering, &c.	0	1	10	0	2¾
	9	7	0	18	10½
Sifting and Sorting.					
1½ boys to pick out red leaf, at 2 annas	0	3	0	0	4½
1 sifting man, at 4 annas	0	4	0	0	6
Wear and tear of sieves	0	0	3	0	0½
	0	7	3	0	11
Packing.					
1 box	1	13	0	3	7½
4 sheets lead, viz. 2 large and 2 small	1	6	6	2	9¾
Labour of lining box with lead, solder, closing lead, closing wooden box, stamping, and nails	0	0	9	0	1
Labour of drying previous to packing, in sun or over *dholes*, including charcoal if latter are used	0	0	9	0	1
Labour of filling box, shaking, and pressing the tea (2 men)	0	0	6	0	0¾
	3	5	6	6	8
Transport.					
Freight to Calcutta for 1 *maund* tea	1	12	0	3	6
Brokerage.					
Landing, lotting, and advertising, per chest	0	14	0	1	9
Brokerage at 1 per cent. on the amount sale, say Rs. 70 per *maund*	0	11	3	1	5
	1	9	3	3	2

Total for 1 *maund* (80 lb.) of tea 16R. 9A. 0P. (1*l.* 13*s.* 1½*d.*)

If more than 2 *maunds* are made per diem, some of the items will be a little less. In large quantity, about 12–13 Rs. (24–26*s.*) would cover everything.

Brick-tea.—The article known as brick-tea is of three kinds. The first, or largest kind, is a cake of coarse green tea, which weighs, when thoroughly dried, about 3½ lb., and is about 1 ft. long by 7 in. wide. These cakes are made in a wooden mould while wet, compressed by a lever-press, and afterward dried, all by hand-labour. When dried, each cake is wrapped in paper and packed in strong baskets, each containing 36 cakes. The cost of this tea per basket is about 28*s.*, and the annual exportation from Kiukiang amounts to 15,000–20,000 baskets. The tea is sent from Kiukiang to Tientsin, whence it goes overland through Mongolia for consumption among the inhabitants of W. and N.-W. Siberia, in the province of Kazan, on the Volga, and by the Kirghis and other tribes. A cake of tea of the same form, but of a much commoner quality, costing about 22*s.*, made by the Chinese at Yang-lout'ung, in Hupeh, is largely consumed in Mongolia.

The second kind of brick-tea is of a finer quality, each cake weighing 1½ lb., and being 8¼ in. long by 5¼ in. wide. It is packed in baskets, each containing 80–90, and costs about 34*s.* per basket. This kind is consumed in W. and S.-W. Siberia, at Kazan, and on the Amoor.

The third kind of brick-tea is made of black-tea dust, each cake weighing 2¼ lb., and being 8½ in. long by 6 in. wide. It is packed in baskets containing 64 cakes each, and costs about 33*s.* per basket. It is consumed throughout Siberia and in E. European Russia by the peasantry. It is made into cakes at Foochow, Kiukiang, and Hankow. The yearly exportation from the three places is about 100,000 baskets. The brick-tea trade of Hankow is rapidly increasing, and the demand becoming greater than the supply. The employment of steam machinery for pressing the bricks has proved a great success, the steam-pressed brick being much better finished than by hand, and more compact and firm, standing transit better, and arriving at its destination little the worse for its journey. With the old method, the bricks, from insufficient pressing power, were liable to chip and crumble at the edges, while great stress is laid on the perfect appearance of the brick by the Siberians. Both methods of manufacturing brick-tea have a serious drawback in the damping of the dust by steam, which robs it of all its fragrance. To remedy this defect, hydraulic presses have been introduced, which turn out small corrugated cakes, weighing ¼ lb. each, retaining the original aroma in all its freshness. It is yet uncertain whether the compressed tea will prove a success, but samples sent to Siberia have been favourably reported on; and though probably the brick will keep its position among the masses, the compressed tea will become popular with the better classes, and if really fine dust be employed in its manufacture, it may, from its portability and cheapness, generally take the place of the leaf-tea at present annually sent overland from Shansi.

The following is the method of producing the brick-tea. There are at present 6 manufactories in Hankow, 3 of which use boilers either for steaming the tea, or both for that and furnishing power for pressing. The dust from which brick-tea is made comes principally from Ningchow in Kiangsi, and Tsung-yang and Yang-lout'ung, in Hupeh, and varies both in fineness and cost according as it belongs to the first, second, or third crop. The first operation is to sift the dust and reject all the sand and rubbish contained in it, usually amounting to about 5 per cent. It is then placed in a winnowing-machine, having 3 different-sized sieves, with troughs corresponding, and passed into baskets. The residue which is too coarse to pass any of the sieves is taken out and trodden until it is reduced to the proper consistency, when it is placed in iron pans over a charcoal fire until it is sufficiently brittle, and is again taken to be winnowed; this operation is repeated until all has been sifted to the requisite degree of fineness. Three sizes are produced, the coarser ones being employed to constitute the brick, while the finest dust is only used as a facing. The dust having been properly sifted, the next step is to prepare it for pressing, by exposing it to the action of steam for 3 minutes; it is this steaming that robs brick-tea of its scent and flavour, and for which a remedy is eagerly sought.

The old-fashioned apparatus of native design consists of 6 iron boilers heated by charcoal, and having spaces above fitted with rattan covers. When the dust is to be steamed, it is spread out on a sheet of cotton cloth, placed over the boiler, and covered up; but with the improved European apparatus, the dust is simply put into iron boxes, and the steam is passed through them. After having been sufficiently steamed to make it adhesive, the dust is put into a strong wooden mould (on the movable cover of which, the trade-mark of the hong or firm is engraved, so as to leave the corresponding impression on the brick), and firmly wedged down. It is then pressed, and placed on one side for 2–3 hours to cool. Each brick should weigh 1 *catty* (1⅓ lb.), and all those that do not come up to the proper standard of weight, or are defective in any way, are rejected and remade. For this purpose, they are taken to an edge-runner mill, constructed of two heavy circular stones, moved by a horizontal wooden bar, and working in a channel, where the condemned bricks are thrown and crushed by the wheels. Having again become dust, the operation already described is repeated. The hand-press turns out 60 baskets a day, with 25 per cent. of failure bricks; while the steam-press produces 80 baskets a day, with only 5 per cent. of bad work, and the saving, by the employment of the improved machinery, amounts to 1 *tael* (5*s.*) a basket, or, according to the above-stated out-turn, 80 *taels* (about 20*l.*) a day. The bricks found to be correct in weight and free from defects are stored in the drying-room for a week, when they are carefully wrapped separately in paper, and packed in bamboo baskets containing 64 each. Green brick-tea is made in the same manner, but of leaf, not dust, and the bricks are larger.

It is expected that in a short time the whole trade will be transferred to Hankow. In addition to brick-tea proper, there is another kind of tea, called "medicine tea," which is composed of coarse leaf and stalks, mixed with various kinds of medicinal herbs, and packed in bundles weighing 64 *catties* (of 1⅓ lb.). It is valued at 5 *taels* (25*s.*) per *picul* (133⅓ lb.), and in the event of the cost of transhipment to Central Asia viâ Tientsin, instead of as hitherto from Shansi, proving sufficiently low, it is expected that the trade will receive increased attention. Owing to the immense quantities of brick-tea now arriving at Tientsin for transport overland, it is anticipated that the sea and river route viâ Tientsin and the Amoor will soon be substituted for camels. Kiukiang exported 681,333 lb. of brick-tea in one year.

Production and Commerce.—America.—Tea culture was attempted more than 10 years ago in California, and great expectations were expressed with regard to the Sacramento Valley in particular; but no material success seems to have been gained. More recently, renewed attention has been given to the subject in the S. States, and a plantation has been selected near Charleston for experiment, it being supposed that the climate of S. Carolina, near the coast, is very suitable for tea-growing. The main difficulty is want of cheap labour. America forms the chief market for green teas.

Azores.—It was officially announced in 1879 that the tea plant was growing luxuriantly in St. Michael's, and that Chinese were engaged to teach the methods of preparing the leaf. Satisfactory results were obtained from experiments.

Ceylon.—Tea cultivation is progressing rapidly in several districts and at various elevations up to 4500–6000 and even 7000 ft., and a very fine-flavoured tea can be produced. In 1880, about 100,000 lb. were exported; and in 1881, up to the close of the season (30th Sept.), 278,590 lb. Ceylon teas distinguished themselves at the Melbourne Exhibition.

China.—The districts specially devoted to tea-farming in China lie between 23° and 25° N. lat., and 115° and 122° E. long., comprising portions of the provinces of Canton, Chekiang, Fokien, Honan, Hupeh, Kiangsi, and Kiangsu. Now that Western science and skill have been introduced with such marked effect in the preparation of tea in India, there is no valid reason for reproducing an account of the complicated Chinese methods; in fact, though China remains by far the largest producer of tea, that country will henceforward be of far less interest to the English tea-grower and merchant than our own tropical possessions. The exports to foreign countries from Amoy in 1879 were:—

Destination.	Congou.	Oolong.	Souchong.	Dust.	Mixed.	Black.	Total.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Great Britain ..	62,149	570,855	..	..	..	..	633,004
United States ..	604,636	15,456,723	40	16,122	116,921	254,863	16,449,305
Straits	112,289	280,620	5,328	..	..	..	398,237
Java	302,608	318,239	3,838	..	..	..	624,685
Siam	63,571	37,452	412	..	..	..	101,435
Manila	17,945	3,657	378	..	240	..	22,220
Saigon	128,177	88,584	300	..	..	..	217,061
Hong Kong ..	374,240	3,048,993	43	..	..	..	3,423,276
Total ..	1,665,615	19,805,123	10,339	16,122	117,161	254,863	21,869,223

The exports from Canton (in *piculs* of 133⅓ lb.) in 1879 were as follows. (The bulk of the black tea sent from these waters is called scented tea, and the flower used for scenting (*Jasminum Sambac*), goes by the name of *mok-lei;* the gardens where this plant is cultivated are principally in the Honam and Fatee suburbs of Canton. The essential oil of this species is considered inferior to that named on p. 1422.)

Destination.	BLACK.								GREEN.					Black.	Green.
	Congou.	Souchong.	Orange Pekoe.	Scented Caper.	Oolong.	Pouchong.	Pekoe.	Total.	Young Hyson.	Hyson.	Imperial.	Gun-powder.	Total.		
														lb.	lb.
Great Britain ..	13	..	193	1,466	..	..	..	1,672	..	..	..	..	..	222,993	
Hong Kong	15,849	4,831	19,244	67,019	436	2,654	42	110,075	40	253	559	2,880	3,733	14,676,691	497,792
Sandwich Islands	469	..	..	..	..	48	1	518	..	..	..	..	..	69,057	
Tientsin	..	..	..	..	..	..	..	..	..	..	..	..	..	13	
Chefoo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
Shanghae	46	..	1	..	..	..	..	48	..	97	..	47	144	6,359	19,224
Total	16,377	4,831	19,438	68,485	436	2,702	43	112,313	40	350	559	2,927	3,877	14,975,113	517,019

Foochow, in 1879, exported 81,421,600 lb. to Europe, the Colonies, and America, besides 4,372,800 lb. to Chinese ports for reshipment. The exports were distributed as follows:—Great Britain, 61,505,584 lb.; Australia, 13,042,800 lb.; Hong Kong, 3,759,883 lb.; S. Africa, 1,023,867 lb.; United States, 888,800 lb.; New Zealand, 857,200 lb.; Continental Europe, 204,400 lb.; Russia, 139,066 lb.

Congous figure for 73,138,133 lb., chiefly of the common and medium kinds; and Souchongs for 4,693,867 lb., mostly to Great Britain, S. Africa, Continental Europe, America, and Hong Kong. The consumption of fine scented teas, such as Orange Pekoe and Caper, as well as of Oolongs, is greatly interfered with by Indian tea. Foochow has now become of but little consideration in the production of Oolongs, being cut out by the increasing quantity prepared in Formosa and Japan under the superintendence of foreigners, and through the inordinate quantity of tea-dust that was mixed with it, the bulk of the Foochow leaf is now manufactured into Saryum Congou. Attempts have been made to introduce Indian tea-seed, to improve the quality of tea from this port, but so far they have not met with any encouragement. A considerable trade has sprung up between this port and Russia, either direct to Odessa, generally in British bottoms, or viâ Tientsin overland to Kiachta. Three Russian firms are connected with this trade, and have establishments here and in the neighbourhood of Yenping, principally for the manufacture of brick-tea by steam process. It is surprising that British firms have not, in the same manner, taken to making brick-tea for exportation. Being portable, and taking up little room, it would be suitable for army supplies. The Russian firms export, besides brick-tea, the best qualities of Pehlings, Panyangs, and Paklums, and can afford to give a higher price than buyers for the English market.

Hankow in 1879 exported 541,213 *piculs* (of 133⅓ lb.) of black tea and dust, value 3,810,197*l.*; 144,756 *piculs* of black brick-tea, 145,957*l.*; and 25,651 *piculs* of green brick-tea, 35,619*l.*

Ichang exported of black tea only 36 *piculs* in 1878, and 91 in 1879. The Chi tea, so called from the place where it is grown,—Lo-tien-chi, near Ichang,—is considered very good, but is scarcely known to foreigners. Hao-fêng, Shi-nanfoo, and Patung are also tea-growing districts, but little of the tea comes to this port. Large quantities of a coarse acrid leaf called tea, and sometimes wild tea, are brought down the river to Ichang, and thence sent to small towns below; it is very cheap, and used only by the poor.

The values of the tea exports from Kiukiang in the years 1877, 1878, 1879 respectively were: 2,333,094*l.*, 2,333,784*l.*, 2,005,086*l.*; the quantities of the various kinds were: black, 176,498 *piculs*, 206,798, 190,150; green, 51,476, 40,316, 40,368; brick, 7452, 11,285, 14,796; leaf, 480, 516, 510; dust, 9236, 9181, 3663.

Tea forms the principal export from Macao, being grown in the neighbouring district of Tayshan. It is brought down in a half-prepared state in bags, and undergoes the necessary firing and manipulation at Macao, where it is packed in boxes, and shipped by river steamer to Hong Kong, the bulk of it finding its way thence to London, a little going also to Australia and New York. The export in 1879 was about 9,000,000 lb. Ningpo exported of green tea, 145,018 *piculs* in 1877, 103,006 in 1878, 127,821 in 1879.

The exports of tea from Shanghae, in *piculs* of 133⅓ lb., in 1879 were :—

Destination.	BLACK.			Leaf.	Dust.	Brick.	Japan, Uncoloured.	GREEN.						Japan, Coloured.
	Congou.	Oolong.	Total.					Young Hyson.	Hyson.	Twankay.	Imperial.	Gun-powder.	Total.	
Great Britain ..	193,390	..	193,389	..	3,908	..	..	16,319	7,585	39	2,430	20,994	47,367	446
Hong Kong	1,521	..	1,521	..	..	357	..	5	53	..	11	13	82	
India	442	..	443	..	..	..	..	..	8,244	..	..	..	8,244	
United States ..	15,019	..	15,019	..	..	..	..	48,227	6,431	848	13,619	52,892	122,019	311
France	444	..	444	..	..	..	..	13	18	..	..	9	40	
Other Europe ..	31	..	31											
Russia (Odessa) ..	695	..	695											
Russian Manchuria	2,748	892	3,640	..	..	7,323								
Japan	98	3	102	..	..	..	..	..	43	..	..	..	43	
Egypt, Colonies, &c.	453	..	453	..	..	..	..	..	9	..	..	..	9	
Straits	7	..	7											
Total foreign ..	214,848	895	215,744	..	3,908	7,680	..	64,564	22,383	887	16,060	73,908	177,804	757
„ Chinese ports	125,607	..	125,607	640	1,412	146,257	91	6	69	..	..	69	146	4
Grand total ..	340,455	895	341,351	640	5,320	153,937	91	64,570	22,452	887	16,060	73,977	177,950	761

About 18,000,000 lb. of black tea were also sent to Siberia.

The exports of black tea from Tamsuy and Kelung were 69,231 *piculs* in 1877, 80,261 in 1878, and 85,033 in 1879. The northern end of the island of Formosa could easily treble its present out-put. Formosan teas are gaining favour in America, but not in England.

Wenchow exported of Congou and unfired teas respectively, 350 and 331 *piculs* in 1878, and 728 and 251 in 1879.

The exports of tea from Wuhu in 1877, 1878, 1879 were: black, ¼, 383, and 2154 *piculs*; green, 3162, 707, and 232. The supplies came chiefly from Ching Hsien, T'ai-p'ing Hsien, and the hills near Ning-kwo-fu. The famous tea of Lin-an-chow, in N. Anhui, which is renowned for its delicate flavour, and accounted the second best in China, remains untouched by the foreign buyer, and the whole production, some 300,000 *piculs* yearly, is prepared exclusively for the Chinese market.

India.—The production of Indian tea has rapidly increased since 1860, when our imports first reached 1,000,000 lb. In 1870, our imports were 13,000,000 lb.; in 1880, 45,000,000 lb., value 3,000,000*l.*; and the figures will soon be 50,000,000 lb. a year. About 200,000 acres are covered with tea-bushes, 15,000,000*l.* of capital invested, and over 250,000 persons employed. Assam occupies the first place. In the Kámrúp district, in 1874, the area was returned at 2687 acres, and the out-turn from 24 plantations was 321,962 lb.; these figures are far short of the totals. In the Darrang district, in 1874, the area under tea was 3856 acres, the out-turn being 1,008,077 lb. In 1872, the black teas produced were :—Congou, 36,659 lb.; Pekoe, 371,233; Broken Pekoe, 175,766; Pekoe Souchong, 215,605; Souchong, 114,659; Broken Souchong, 55,691; Pekoe fannings, 14,188; broken tea, 65,213; fannings, 135,845; green, 6000 lb. In the Nowgong district in 1872, 1278½ acres were occupied by mature plants, and a total of 12,319 acres was selected for tea culture. The yield was :—Congou, 20,000 lb.; Congou and Souchong, 9500; Souchong, 28,276; Pekoe, 217,794; Pekoe and broken Pekoe, 47,604; broken Pekoe, 4450; broken Pekoe and fannings, 15,397; fannings, 13,120; total, 370,901; average yield per acre of mature plants, 288 lb. In the Sibsagar district, which is second only to Cachar among all the tea-growing districts of India, the area under tea in 1874 was 22,573 acres; the total out-turn, 4,528,329 lb. The total area taken up for tea to the end of 1874 was 108,050 acres. The approximate yield in 1872 was:—Congou, 210,026 lb.; Pekoe, 1,006,874; Pekoe Souchong, 85,266; Souchong, 526,150; fannings, 866,784; total, 3,199,500 lb. The average yield per acre of mature plants was 238 lb. The exports from Lakhimpur in 1871 were:—546¾ tons, 43,650*l.* The area in 1874 was 89,370 acres (11,680 in bearing); total out-turn, 1,811,920 lb.

Sylhet, in 1874, had 19,190 acres in tea-gardens, of which 5297 were actually under cultivation. The out-turn was 567,567 lb. In 1876, it was estimated at 655,600 lb. The average per acre of mature plants (upwards of 2 years) is 111 lb., as against 200 lb. for the whole province. Sylhet and Cachar combined gave 4,600,000 lb. in 1870, and 9,000,000 lb. in 1878. Darjeeling, the Terai, and the Dooars had 144 gardens, yielding 7,530,940 lb. in 1878, and 152 gardens, affording 5,538,040 lb. in 1879. Chittagong produced about 1,000,000 lb. in 1878; and other outlying districts, about 500,000 lb.

Japan.—The tea-plant grows well here, and tea forms one of the chief exports to foreign countries, not even excluding China itself. The best leaf comes from the neighbourhood of Uji, in the province of Yamashiro, to the S.-E. of Kiôto; but tea is also largely produced in the fertile district in the east of the main island, and exported from Yokohama. Japanese tea is driving Chinese green tea from the American market; 11,000,000 lb. went there in 1879.

Java.—The tea-gardens of Java are situated mostly in the Batavian department of Buitenzorg, and in the Preanger Regencies. The production of tea was stated at 5,700,000 lb. in 1879. The Chinese variety is the only one grown to any extent; trials are being made with the Assam shrub, but have not yet had any practical result. The Java teas are somewhat similar to Assams, and are readily saleable in England, where they are chiefly used for mixing with Indian. The 1879 crop was exported thus:—England, 31,814 *piculs* and cases; Holland, 31,382; Persian Gulf, 930; Australia, 440; Japan, 100; Singapore, 68.

Adulterants and Substitutes.—The adulterants of tea are exceedingly numerous, and the Chinese manifest wonderful skill in this direction. Among the first class of adulterants, viz. foreign leaves, are included those of the ash, plum, dog-rose, *Rhamnus spp.*, *Rhododendron spp.*, and *Chrysanthemum spp.*, as well as tea-stalks and paddy-husks, all for the purpose of increasing the bulk; also the scented flowers of *Olea fragrans*, *Chloranthus inconspicuus*, *Aglaia odorata*, *Camellia Sasanqua*, *Gardenia florida*, *Jasminum Sambac* and other species, to impart fragrance to inferior samples. Sometimes the true tea is almost replaced by a factitious compound known as "lie-tea," composed of a little tea-dust, blended with foreign leaves, sand, and magnetic iron by means of a solution of starch, and coloured with graphite, turmeric, indigo, Prussian blue, or China clay, according to the kind of tea it is intended to simulate. Mineral adulterants are used to give weight and colour. In addition to those employed in the fabrication of lie-tea, are soapstone and gypsum. The adulteration practised after the arrival of the tea in this country embraces the substitution or admixture of the leaves of the beech, box, elm, hawthorn, horse-chestnut, fancy oak, plane, bastard plane, poplar, sloe, sycamore, and willow, and artificial colouring by means of cutch, indigo, Dutch and rose pinks, sulphate of iron, Venetian red, chromates of lead and potash, carbonates of copper, lime and magnesia, arsenite of copper, and Prussian blue.

Besides the well-known varieties or species of *Thea*, two new kinds have recently been described by Consul E. Colborne Baber. One is grown by the monks on Mount Omi (Ngomi), and gives an infusion tasting like coarse Congou highly sweetened with brown sugar. The other is found wild in the uninhabited wilderness west of Kiating and south of Yachow, at 6000 ft. and upwards, notably on the Hwang-mu-chang plateau, among the gorges of the Tung river; it is a shrub 15 ft. high with a stem 4 in. thick; every part except the root is used in the infusion, which has a buttery flavour. A third new species is reported from the neighbourhood of Trebizonde where the leaves are picked and sun-dried, and sent in large quantities to Persia.

The name "tea" has been popularly applied to many other plants, the principal being as follows:—Abyssinian or Arabian (*Catha* [*Celastrus*] *edulis*), the leaves of which are used by the Arabs in the preparation of a beverage possessing similar properties to tea; Appalachian (*Viburnum cassinoides* and *Prinos glaber*), the infusion of the latter resembling maté; Australian (*Leptospermum* and *Melaleuca spp.*): the leaves of *L. lanigerum*, of Tasmania and S.-E. Australia, were used as tea by the early colonists, for *Melaleuca* see Cajuput-oil, p. 1418; Bencoolen (*Glaphyria nitida*), whose leaves are infused like tea by the Malays; blue mountain or golden rod (*Solidago odora*); Botany Bay (*Smilax glyciphylla*), in Australia; Bourbon or Faham (*Angræcum fragrans*), largely grown in Bourbon, and the leaves made into an aromatic tea-like beverage; Brazilian (*Stachytarpha* [*Stachytarpheta*] *jamaicensis*), whose leaves are said to possess medicinal virtues, being sold in Austria as "Brazilian tea," and sometimes used to adulterate tea; bush (*Cyclopia genistoides*), the leaves of which have a tea-like fragrance, and are used in infusion at the Cape to promote expectoration; Canary (*Sida canariensis*); Carolina (*Ilex vomitoria*); coffee-leaf (see Coffee, p. 707); gout (*Cordia globosa*), in the W. Indies; Jesuits' (*Psoralea glandulosa*), the *culen* of Chili, whose leaves give a not very aromatic infusion, and are more useful as a vermifuge and stomachic; Labrador (see Narcotics—Ledum, p. 1308); lemon-grass (see p. 1421), the leaves of which are used like tea in the interior of India; Malay (*Eugenia variabilis*), see also Bencoolen; Mexican (*Ambrina ambrosioides*), used medicinally as a vermifuge and anti-spasmodic (also *Psoralea glandulosa*); mountain (*Gaultheria procumbens*), whose leaves are used to flavour tea, or as a substitute (see also Wintergreen-oil, p. 1431); New Jersey (*Ceanothus americanus*), the leaves of which were used as tea during the American War of Independence; New Zealand (*Leptospermum scoparium*), allied to and used like Australian tea; Oswego (*Monarda didyma*), so called from the leaves being sometimes used as tea in America; paigle- (pagle, peagle) tea, an infusion of the dried blossoms of the cowslip (*Primula veris*), possessing narcotic properties, and drunk in some counties of England; Paraguay-tea or maté is an infusion of the leaves of *Ilex paraguayensis* and probably *I. Gongonha* and *I. theezans*, which are prepared by roasting the branches on hurdles over a wood fire, and then beating the dried leaves to powder by sticks on a hard floor; 3 kinds are distinguished: *caa-cuys*, the half-expanded leaf-buds; *caa-miri*, the leaf deprived of midrib and veins without roasting; *caa-guaza* or *yerva de polos*, the whole leaf with the petioles and small branches roasted; the consumption in S. America is 8 million lb. yearly; saloop-tea is an infusion of sassafras (called "sassafras-tea") flavoured with milk and sugar, and said to be formerly drunk by the working classes in London; South Sea, see Carolina; sweet, see Botany Bay; theezan-tea is an infusion of the leaves of the *tia* (*Sageretia theezans*), native of Penang, the Philippines, and S. China, and said to be sometimes used as tea by the poorer Chinese; W. Indian (*Capraria biflora*); wild (*Amorpha canescens*).

Imports, Exports, and Values.—Our imports of tea in 1880 were:—From China, 158,195,142 lb., 8,349,699*l.*; Bengal and Burma, 44,437,406 lb., 3,032,354*l.*; Holland, 2,426,738 lb., 120,738*l.*; Bombay and Sind, 618,062 lb., 34,840*l.*; United States, 335,804 lb., 19,313*l.*; Straits Settlements, 242,222 lb., 13,975*l.*; Japan, 213,804 lb., 11,552*l.*; Ceylon, 150,395 lb., 10,132*l.*; Madras, 82,643 lb., 5728*l.*; other countries, 269,284 lb., 15,067*l.*; total, 206,971,570 lb., 11,613,398*l.*; retained for home consumption, 158,570,842 lb., 3,964,290*l.*

Our exports in 1880 were:—To Germany, 22,713,650 lb., 1,394,008*l.*; British N. America, 6,257,384 lb., 406,943*l.*; Russia, 5,557,571 lb., 333,656*l.*; Holland, 3,176,343 lb., 187,026*l.*; Denmark, 832,951 lb., 55,481*l.*; Chili, 727,421 lb., 41,251*l.*; Portugal, Azores, and Madeira, 662,033 lb., 57,489*l.*; United States, 652,179 lb., 38,014*l.*; Channel Islands, 611,253 lb., 38,341*l.*; Morocco, 432,629 lb., 38,318*l.*; France, 424,042 lb., 33,371*l.*; Brazil, 395,572 lb., 33,070*l.*; Turkey, 348,832 lb., 22,593*l.*; other countries, 1,802,986 lb., 124,007*l.*; total, 44,594,846 lb., 2,803,568*l.*

The approximate London market values per lb. of teas in bond (duty 6*d.* a lb.) are:—Congou: brown leaf siftings, 4–10*d.*, ordinary to leafy, 7–10*d.*, good ordinary to middling, 7½–11*d.*, ditto export kinds, 8¼–11½*d.*, fair to medium, 9–17*d.*; Kaisow, 2nd class, 14–20*d.*, 1st to finest, 18–27*d.*; black leaf, common, 7¼–14½*d.*, good common, 8¼–32½*d.*, fair to medium, 9½–17*d.*; Oopack and Moning, 8–27*d.*; ditto fine to finest, 19–30*d.*; Tayshan, 7–18*d.*; Ning Yong and Oolong, 8–24*d.*; Souchong, common to good, 8¼–20*d.*, fine to finest, 12–24*d.*; Flowery Pekoe, 12–19*d.*, fine to finest, 19–40*d.*; Caper, scented, 6½–15*d.*, fine to finest, 10½–21*d.*; Orange Pekoe, scented, 6–18*d.*, fine to finest, 12–24*d.*; Twankay, 4½–13*d.*; Hyson, common, 6¼–14*d.*, fair to fine, 10–27*d.*, finest, 21–42*d.*; Young Hyson, common, 5½–14*d.*, good to finest, 9–30*d.*; Imperial, 6–15*d.*, good to superior, 10–22*d.*; Gunpowder, 7–19*d.*, good to finest, 12–42*d.*; Canton, 8–12*d.*; Japan, uncoloured, 8–16*d.*; Indian: broken, 8½–28*d.*, Congou, 9–16*d.*, Souchong, 9–24*d.*, Pekoe Souchong, 12–32*d.*, Pekoe, 10½–38*d.*; Flowery Pekoe, 18–45*d.*

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(See Beverages—Tea.)

TIMBER (Fr., *Bois d'œuvre*; Ger., *Nutzholz*).

Properly speaking, the term "timber" is confined to those kinds of wood which are eligible for building purposes; but in the present article, it will be extended to embrace all useful woods, except such as have been already described under Drugs (Quassia, p. 820); Dyestuffs (Barwood, p. 855; Brazil-wood, p. 856; Camwood, p. 856; Logwood, p. 862; Sanders-wood, p. 867; Sapanwood, p. 867); Perfumes (Sandal-wood, pp. 1527–8); and Tannin (Quebracho, p. 1988). They will be arranged in alphabetic order. The terms used in describing the characters of the various woods may be explained once for all. The "cohesive force" is the weight required to pull asunder a bar of the wood in the direction of its length; the figures denoting the strength, toughness, and stiffness, are in comparison with oak, which is taken as the standard, and placed at 100 in each case; the "crushing-force" is the resistance to compression; the "breaking-weight" is the weight required to break a bar 1 in. sq. supported at two points 1 ft. apart, and the weight suspended in the middle.

For more detailed information regarding the peculiar properties of building-woods, and the many methods of preserving timber, the reader is referred to the new edition of Tredgold's Carpentry, by Hurst, and to other works quoted in the Bibliography at the end of this article; a copious list of books on forestry will be found in Daydon Jackson's 'Vegetable Technology.'

Acacia or American Locust-tree (*Robinia pseudo-acacia*).—This beautiful tree, of considerable size and very rapid growth, inhabits the mountains of America from Canada to Carolina, its trunk attaining the mean size of 32 ft. long and 23 in. diam. The seasoned wood is much valued for its durability, surpassing oak. It is admirable for building, posts, stakes, palings, treenails for ships, and other purposes. Its weight is 49–56 lb. a cub. ft.; cohesive force, 10,000–13,000 lb.; and the strength, stiffness, and toughness of young unseasoned wood are respectively 95, 98, and 92.

Alder (*Alnus glutinosa*).—This small tree inhabits wet grounds and river-banks in Europe and Asia, seldom exceeding 40 ft. high and 24 in. diam. The wood is extremely durable in water and wherever it is constantly wet; but it soon rots on exposure to the weather or to damp, and is much attacked by worms when dry. It is soft, works easily, and carves well; but it is most esteemed for piles, sluices, and pumps, and has been much cultivated in Holland and Flanders for such purposes. Its weight is 34–50 lb. a cub. ft.; cohesive force, 5000–13,900 lb.; strength, 80; stiffness, 63; toughness, 101. It is one of the woods used in making gunpowder (see p. 882).

Alerce-wood (*Callitris quadrivalvis*).—This is the celebrated citrus-wood of the ancient Romans, the timber of the gum sandarach tree (see pp. 1681–2). The wood was esteemed above all others for roofing temples and for tables, and is employed in the cathedral of Cordova. Among the luxurious Romans, the great merit of the tables was to have the veins arranged in waving lines or spirals, the former called "tiger" tables and the latter "panther." Others were marked like the eyes on a peacock's tail, and others again appeared as if covered with dense masses of grain. Some of these tables were 4–4½ ft. diam. The specimens of the tree now existing in S. Morocco resemble small cypresses, and are apparently shoots from the stumps of trees that have been cut or burnt, though possibly their stunted habit may be due to sterility of soil. The largest seen by Hooker and Ball in 1878 were in the Ourika valley, and were about 30 ft. high. The stems of the trees swell out at the very base into roundish masses, half buried in soil, rarely attaining a diameter of 4 ft. It is this basal swelling, whether of natural or artificial origin, which affords the valuable wood, exported in these days from Algiers to Paris, where it is used in the richest and most expensive cabinet-work. The unique beauty of the wood will always command for it a ready market, if it be allowed to attain sufficient size, and the tree is certainly deserving of earnest attempt to naturalize it in the botanic gardens of some of our tropical colonies, before it becomes extinct at the hands of the apathetic Moors, who are wasting the wood for building and fuel.

Alerse (*Libocedrus tetragona*).—This is a Chilian tree, affording a timber which is largely used on the S. Pacific coast of America, and an important article of commerce. It gives spars 80–90 ft. long, and 800–1500 boards. Its grain is so straight and even that shingles split from it appear to have been planed.

Ash (*Fraxinus excelsior*).—The common ash is indigenous to Europe and N. Asia, and found throughout Great Britain. The young wood is more valuable than the old; it is durable in the dry, but soon rots by exposure to damp or alternate wetting, and is very subject to worm when felled in full sap. It is difficult to work and too flexible for building, but valuable in machinery, wheel-carriages, blocks, and handles of tools. The weight is 34–52 lb. a cub. ft.; cohesive force, 6300–17,000 lb.; strength, 119; stiffness, 89; toughness, 160.

Assegai-wood or Cape Lancewood (*Curtisia faginea*).—This tree, the *oomhlebe* of the African natives, gives a very tough wood, used for wheel-spokes, shafts, waggon-rails, spears, and turnery, weighing 56 lb. a cub. ft.

Beech (*Fagus sylvatica*).—The common beech inhabits most temperate parts of Europe, from

Norway to the Mediterranean, and is plentiful in S. Russia. It is most abundant in the S. and Midland counties of England, growing on chalky soils to 100 ft. high and 4–6 ft. diam. Wood grown in damp valleys becomes brittle on drying; it is very liable to destruction by worms, decays in damp situations, less in a dry state, but least of all when constantly under water. It is thus most useful for piles, and for knees and planking of ships. Its uniform texture and hardness make it very valuable for tools and common furniture. It is also used for carriage-panels and wooden tramways. Its weight is 43–53 lb. a cub. ft.; cohesive force, 6070–17,000 lb.; strength, 103; stiffness, 77; toughness, 138. (See Oils, p. 1378; Tar, p. 1683.)

Beech [American].—Two species of *Fagus* are common in N. America,—the white (*F. sylvestris*), and the red (*F. ferruginea*). The perfect wood of the former is frequently only 3 in. in a trunk 18 in. diam., and it is of little use except for fuel. The wood of the latter, which is almost exclusively confined to the N.-E. States, Canada, New Brunswick, and Nova Scotia, is stronger, tougher, and more compact, but so liable to insect attacks as to be little used in furniture; yet it is very durable when constantly immersed in water.

Birch (*Betula spp.*).—The common birch (*B. alba*) is less important as a source of wood than as affording an empyreumatic oil (see pp. 1417–8, 1684). Its wood is neither strong nor durable, but is easily worked, moderately hard, and of straight and even grain, rendering it useful for chair-making, cabinet-making, and light turnery. Memel exported by sea in 1880, 175,051 birch staves, value 340*l.*, and 45,596 logs, value 832*l.* 10*s.*

The American red birch (*B. rubra*) has similar uses. The black or cherry birch (*B. lenta* [*nigra*]) of N. America is superior to all others, and imported in logs 6–20 ft. long and 12–30 in. diam., for furniture and turnery. Quebec birch is worth 3*l.* 5*s.*–4*l.* 15*s.* a load.

Box (*Buxus sempervirens*).—The common evergreen box is a native of Europe as far as 52° N. lat., and is abundant in S. and E. France, Spain, Italy, the Black Sea coast, Persia, N. India, China, and Japan. For some years past, the supply of this important wood has diminished in quantity and risen in price. It is mainly derived from the forests of the Caucasus, Armenia, and the Caspian shores. The wood of the best quality comes from the Black Sea forests, and is principally shipped from the port of Poti. The produce of the Caspian forests, known in the trade as "Persian," used also to be exported through the Black Sea from Taganrog. This found its way, after the commencement of the Russo-Turkish war, viâ the Volga canal, to St. Petersburg. The produce of the Caspian forests is softer and inferior in quality to that of the Black Sea. It is a large article of trade with Russia, reaching Astrakhan and Nijni-Novgorod in the spring, and being sold during the fair. It recently amounted to 130,000 *poods* (of 36 lb.). True Caucasian boxwood may be said to be commercially non-existent, almost every marketable tree having been exported. The value of the yet unworked Abkhasian forests has been much exaggerated, many of the trees being either knotted or hollow from age, and most of the good wood having been felled by the Abkhasians previous to Russian occupation. The boxwood at present exported from Rostov, and supposed to be Caucasian, comes from the Persian provinces of Mazanderan and Ghilan, on the Caspian. Boxwood is characterized by excessive hardness, great weight, evenness and closeness of grain, light colour, and capacity for taking a fine polish. Hence it is very valuable for wood-engraving (see p. 1610), turning, and instrument-making. The Minorca box (*B. balearica*), found in several of the Mediterranean islands, and in Asia Minor, yields a similar but coarser wood, which probably finds its way into commerce.

The shipments of boxwood from Taganrog were 4681 tons in 1878, 2904 tons in 1879, and 1839 tons, 23,177*l.*, in 1880. The exports from Trebizonde were, in 1879, 702 cwt. to Turkey, and 7040 cwt. to Great Britain, total value 1161*l.*; in 1860, 541 cwt., 51*l.*, to Great Britain. Ghilan exported to Russia 8846*l.* worth in 1878, and 4444*l.* worth in 1879. Poti despatched 12,640 *poods* (of 36 lb.) in 1877–8. The approximate value of Turkey box is 6–20*l.* a ton.

Broadleaf or Almond (*Terminalia latifolia*).—This is a Jamaica tree, growing 60 ft. high to the main branches, and 3½–5 ft. diam. It is used for timbers, boards, shingles, and staves. Its weight is 48 lb. a cub. ft.; crushing-force, 7500 lb.; breaking-weight, 750 lb.

Bullet-tree (*Mimusops Balata*).—This tree is found in the W. Indies and Central America. Its wood is very hard and durable, and fitted for most outside work; it is used principally for posts, sills, and rafters. It warps much in seasoning, splits easily, becomes slippery if used as flooring, and is very liable to attacks of sea-worms. Its weight is 65½ lb. a cub. ft.; crushing-force, 14,330 lb. (See Resins—Balata, p. 1635, Chicle, 1639.)

Calophyllum. See Tamanu, p. 2021.

Cedar [Australian Red] (*Cedrela australis*).—This tree is a native of Australia, where it has been almost exterminated, the timber being found so useful in house-building (for joinery, doors, and sashes) and boat-building. Its weight is 35 lb. a cub. ft.; breaking-weight, 471 lb.

Cedar [Bermuda] (*Juniperus bermudiana*).—This species is a native of the Bermudas and Bahamas. Its wood much resembles that of Virginian Cedar, and is used for similar purposes, as well as for ship-building. It is extremely durable when ventilated and freed from sap-wood. It lasts 150–200 years in houses, and 40 years as outside ship-planking. It is difficult to get above 8 in. sq. Its weight is 46–47 lb. a cub. ft.

Cedar of Lebanon (*Abies Cedrus* [*Cedrus Libani*]).—This evergreen tree is a native of Syria, and probably Candia and Algeria. The trunk reaches 50 ft. high and 34–39 in. diam. The wood is said to be very durable, and to have been formerly extensively used in the construction of temples. It is straight-grained, easily worked, readily splits, and is not liable to worm. Its weight is 30–38 lb. a cub. ft.; cohesive force, 7400 lb. a sq. in.; strength, 62; stiffness, 28; toughness, 106. (See Oils, p. 1419.)

Cedar [New Zealand] (*Libocedrus Bidwillii* and *L. Doniana*).—Of these species, the latter, the *kawaka* of the natives, is a fine timber tree 60–100 ft. high, yielding heavy, fine-grained wood, useful in fencing, house-blocks, piles, and sleepers. It weighs 30 lb. a cub. ft.; breaking-weight, 400 lb. The first species gives a soft, porous wood, useless for timber purposes.

Cedar [Virginian Red] (*Juniperus virginiana*).—This small tree (45–50 ft. high and 8–18 in. diam.) inhabits dry rocky hillsides in Canada, the United States, and W. Indies, and flourishes in Britain. The wood is much used in America for wardrobes, drawers, boxes, and furniture, being avoided by all insects on account of its strong odour and flavour. It is light, brittle, and nearly uniform in texture. It is very extensively employed for covering graphite pencils, being imported in pieces 6–10 in. sq. It weighs 40½ lb. a cub. ft. (See Oils, p. 1419.)

Cedar [W. Indian or Havanna] (*Cedrela odorata*).—This tree is a native chiefly of Honduras, Jamaica, and Cuba, having a stem 70–80 ft. high and 3–5 ft. diam., and exported in logs up to 3–4 ft. sq. Its wood is soft, porous, and brittle, and used chiefly for cigar-boxes and the inside of furniture. It makes durable planks and shingles. Its weight is 36 lb. a cub. ft.; crushing-weight, 6600 lb.; breaking-weight, 400 lb. Costa Rica exported from San José, in 1875, 81 boards, 113 planks, and 7306 logs of cedar; in 1878, 365 planks and 645 logs. The exports from British Honduras were 18,923 ft. in 1876, 77,582 in 1877, 87,129 in 1878. The approximate London market values are 4–5¼*d.* a ft. for Cuba cedar, and 4–5¼*d.* for Honduras, &c.

Cedar Boom (*Widdringtonia juniperoides*).—This tree is found in N. and W. Cape Colony, and its wood is used for floors, roofs, and other building purposes, but will not stand the weather.

Chestnut (*Castanea vesca*).—This, the sweet or Spanish chestnut, is said to be a native of Greece and W. Asia, but grows wild also in Italy, France, Spain, N. Africa, and N. America. It lives to 1000 years, but reaches its prime at about 50, when the stem may be 40–60 ft. long and 3–6 ft. diam. The wood is hard and compact: when young, it is tough and flexible, and as durable as oak; when old, it is brittle and shaky. It does not shrink or swell so much as other woods, and is easier to work than oak; but soon rots when built into walls. It is valued for hop-poles, palings, gate-posts, stakes, and similar purposes. Its weight is 43–54 lb. a cub. ft.; cohesive force, 8100 lb.; strength, 68; stiffness, 54; toughness 85. (See Nuts, p. 1352; Tannin, p. 1982.)

Cypress (*Cupressus sempervirens*).—This tree is abundant in Persia and the Levant, and cultivated in all countries bordering the Mediterranean, thriving best in warm sandy or gravelly soil, and reaching 70–90 ft. high. Its wood is said to be the most durable of all. For furniture, it is stronger than mahogany, and equally repulsive to insects. In Malta and Candia, it is much used for building. It weighs about 40–41 lb. a cub. ft.

Deal [White], White Fir, or Norway Spruce (*Abies excelsa*).—This tree inhabits the mountainous districts of Europe, and extends into N. Asia, being especially prevalent in Norway. It runs to 80–100 ft. high, and about 2–3 ft. max. diam. The tree requires 70–80 years to reach perfection, but is equally durable at all ages. It is much imported in spars and deals, the latter about 12 ft. long, 3 in. thick, and 9 in. wide. The wood glues well, and is very durable while dry, but much more knotty than Northern Pine. It is fine-grained, and does well for gilding on, also for internal joinery, lining furniture, and packing-cases. A principal use is for scaffolds, ladders, and masts, for which purpose it is largely imported from Norway in entire trunks, 30-60 ft. long, and 6–8 in. max. diam. It is shipped from Christiania, Friedrichstadt, Drontheim, Gottenburg, Riga, Narva, St. Petersburg, &c. Christiania deals and battens are reckoned best for panelling and upper floors; Friedrichstadt have small black knots; lowland Norway split and warp in drying; Gottenburg are stringy and mostly used for packing-cases; Narva are next in quality to Norway, then Riga; St. Petersburg shrink and swell even after painting. The wood is generally light, elastic, tough, easily worked, and extremely durable when properly seasoned. It weighs 28-34 lb. a cub. ft.; cohesive force, 8000–12,000 lb. a sq. in.; strength, 104; stiffness, 104; toughness, 104. (See Rosin, p. 1680; Pine-oils, p. 1408; Turpentine-oils, p. 1431; Pitch, pp. 1678–9; Tar, p. 1684.)

Deodar (*Cedrus Deodara*).—This tree is found in the Himálayas at 5000–12,000 ft., and on the higher mountains from Nepal to Kashmir, measuring 150–200 ft. high, and over 30 ft. circ. Its wood is extremely valuable for all carpentry, and most generally used in the Punjab for building. Its weight is 37 lb. a cub. ft.; breaking-weight, 520 lb.

Dogwood.—The American dogwood (*Cornus florida*) is a tree 30 ft. high, common in the woods of many parts of N. America. Its wood is hard, heavy, and close-grained, and largely used locally for tool-handles; it has been imported into England with some success as a substitute for box in making shuttles for textile machinery.

The black dogwood or alder buckthorn (*Rhamnus Frangula*) is abundant in Asia Minor, and affords one of the best wood charcoals for gunpowder-making (see p. 882). Its berries probably contribute to the yellow dyestuff known as Persian berries (see p. 864).

Doorn Boom or Kameel Boom (*Acacia horrida*).—This tree is a native of S. Africa, and affords small timber used for fencing, spars, fuel, and charcoal. (See Cape Arabic, p. 1632.)

Ebony (*Diospyros spp.*).—The best and most costly kind of ebony, having the blackest and finest grain, is the wood of *D. reticulata*, of Mauritius. Two E. Indian species, *D. Melanoxylon* and *D. Ebenaster*, also contribute commercial supplies, and another kind is obtained from *D. Ebenum*, of Ceylon. The heart-wood of the trunk of these trees is very hard and dense, and is largely used for fancy cabinet-making, mosaic work, turnery, and small articles. The approximate London market values are 5–20*l.* a ton for Ceylon, and 3–12*l.* for Zanzibar, &c.

Elm (*Ulmus spp.*).—Five species of elm are now grown in Britain:—The common rough-leaved (*U. campestris*) is frequent in scattered woods and hedges in S. England, and in France and Spain, attaining 70–80 ft. high and 4 ft. diam. Its wood is harder and more durable than the other kinds, and is preferred for coffins, resisting moisture well. The cork-barked (*U. suberosa*) is common in Sussex, but the wood is inferior. The broad-leaved wych-elm or wych-hazel (*U. montana*) is most cultivated in Scotland and Ireland, reaching 70–80 ft. high and 3–4½ ft. diam. The smooth-leaved wych-elm (*U. glabra*) is abundant in Essex, Hereford, the N. and N.-E. counties of England, and in Scotland, growing to a large size. The wood is tough and flexible, and preferred for wheel-naves. The Dutch elm (*U. major*), the smallest of the five, is indigenous to Holland; its wood is very inferior. Elm-trunks average 44 ft. long and 32 in. diam. The wood is very durable when perfectly dry or constantly wet. It is not useful for general building, but makes excellent piles, and is used in wet foundations, waterworks, and pumps; also for wheel-naves, blocks, keels, and gunwales. It twists and warps in drying, shrinks considerably, and is difficult to work; but is not liable to split, and bears the driving of bolts and nails very well. Its weight is 34–50 lb. a cub. ft.; cohesive force, 6070–13,200 lb.; strength, 82; stiffness, 78; toughness, 86.

These species of elm are indigenous to N. America, and have similar uses to the European kinds:—The common American (*U. americana*) grows in low woods from New England to Canada, reaching 80–100 ft. high; its wood is inferior to English. The Canada rock or mountain (*U. racemosa*) is common to Canada and the N. States; the wood is used in boat-building, but is very liable to shrink, and gets shaky by exposure to sun and wind; its weight is 47–55 lb. a cub. ft. The slippery (*U. fulva*) gives an inferior wood, though much used for various purposes. Quebec elm is valued at 4–5*l.* a load.

Fir [Silver] (*Picea pectinata*).—This large tree (100 ft. high, and 3–5 ft. diam.) is indigenous to Europe, Asia, and N. America, growing in British plantations. It is said to attain its greatest perfection in this country at 80 years. The wood is of good quality, and much used on the Continent for carpentry and ship-building. Floors of it remain permanently level. It is liable to attacks of the worm, and lasts longer in air than in water. It weighs about 25½ lb. a cub. ft.

Greenheart or Bibiri (*Nectandra Rodiœi* [*leucantha*]).—This celebrated ship-building wood is a native of British Guiana, and has been largely exported from Demerara to English dockyards. It gives balks 50–60 ft. long without a knot, and 18–24 in. sq., of hard, fine-grained, strong, and durable wood. It is reputed proof against sea-worms, and placed in the first class at Lloyd's; it is very difficult to work, on account of its splitting with great force. Its weight is 58–65 lb. a cub. ft.; crushing-weight, 12,000 lb.; breaking-weight, 1424 lb. (See Starch, p. 1823.)

Gum [Blue] (*Eucalyptus Globulus*).—This Australian and Tasmanian tree is of rapid growth, and often reaches 150–300 ft. high and 10–20 ft. diam. Its wood is hard, compact, difficult to work, and liable to split, warp, and shrink in seasoning. It is used for general carpentry and wheel-spokes. Its weight is 60 lb. a cub. ft.; crushing-force, 6700 lb.; breaking-weight, 550–900 lb. (See Eucalyptus-oils, p. 1420; Kino, p. 1668; Tannin, p. 1993.)

Gum [White or Swamp] (*E. viminalis*).—This tree is found chiefly in Tasmania, and a variety called the Tuvart occurs in W. Australia. The wood is valued for its great strength, and is sometimes used in ship-building, but more in house-building, and for purposes where weight is not an objection. It is sound and durable, shrinks little, but has a twisted grain, which makes it difficult to work. Its weight is about 70 lb. a cub. ft.; crushing-force, 10,000 lb.; breaking-weight, 730 lb.

Hickory or White Walnut (*Carya* [*Juglans*] *alba*).—There are about a dozen species of hickory, natives of N. America, forming large forest trees. Their timber is coarse-grained, and very strong, tough, and heavy; but is unsuited for building, as it does not bear exposure to the weather, and is much attacked by insects. It is extensively used where toughness and elasticity are required, such as for barrel-hoops, presses, handles, shafts and poles of wheel-carriages, fishing-rods, and even light furniture. The most important is the shell-bark, scaly-bark, or shag-bark (*C. alba*), common throughout the Alleghanies from Carolina to New Hampshire, growing 80–90 ft. high and 2–3 ft. diam. (See Nuts, p. 1358; Oils, p. 1391.)

Ironbark (*Eucalyptus resinifera*).—This rugged tree is found in most parts of the Australian continent, frequently reaching 100–150 ft. high and 3–6 ft. diam., the usual market logs being 20–40 ft. long and 12–18 in. sq. Its wood is straight-grained, very dense, heavy, strong, and durable, but very difficult to work. It is liable to be shaky, and can only be employed with advantage in stout planks or large scantlings. Its weight is 64½ lb. a cub. ft.; crushing-force, 9921 lb.; breaking-weight, 1000 lb.

Ironwood [**Cape**] (*Olea undulata*)—This S. African wood, the *tambooti* or *hooshe* of the natives, is very heavy, fine-grained, and durable, and is used for waggon-axles, wheel-cogs, spokes, telegraph-poles, railway-sleepers, and piles. This is the "black" ironwood. The "white" (*Vepris lanceolata*) is used for similar purposes.

Jack, or Ceylon Mahogany (*Artocarpus integrifolia*).—This useful tree is a native of the E. Archipelago, and is widely cultivated in Ceylon, S. India, and all the warm parts of Asia, mainly as a shade-tree for coffee and other crops. Its wood is in very general use locally for making furniture; it is durable, and can be got in logs 21 ft. long and 17 in. diam. Its weight is 42 lb. a cub. ft.; breaking-weight, 600 lb.

Jack [**Jungle**], **or Anjilli** (*A. hirsuta*).—This species is remarkable for size of stem, and is found in Bengal, Malabar, and Burma. Its wood is strong and close-grained, and considered next in value to teak for ship-building. Its weight is 38–49 lb. a cub. ft.; cohesive force, 13,000–15,000 lb.; breaking-weight, 740 lb.

Jarrah, Australian Mahogany, or Flooded or Red Gum (*Eucalyptus marginata*).—This tree attains greatest perfection in W. Australia, reaching 200 ft. high. Its wood is hard, heavy, close-grained, and very durable in salt and fresh water, if cut before the rising of the sap. It is best grown on the hills. It resists sea-worms and white ants, rendering it specially valuable for ships, jetties, railway-sleepers and telegraph-posts, but shrinks and warps considerably, so that it is unfit for floors or joinery. Logs may be got 20–40 ft. long and 11–24 in. sq. Its weight is 62½ lb. a cub. ft.; crushing-force, 7000 lb.; breaking-weight, 500 lb.

Kanyin (*Dipterocarpus alatus*).—This magnificent tree is found chiefly in Pegu and the Straits, reaching 250 ft. high. Its wood is hard and close-grained, excellent for all house-building purposes, but not durable in wet. Its weight is 45 lb. a cub. ft.; breaking-weight, 750 lb.

Another species (*D. turbinatus*), found in Assam, Burma, and the Andamans, is similar, and much used by the natives in house-building.

Kauri, Cowrie, or Pitch-tree (*Dammara australis*).—This gigantic conifer is a native of New Zealand, growing 80–140 ft. high, with a straight clean stem 4–8 ft. diam. The wood is close, even, fine-grained, and free from knots. It is chiefly used and well adapted for masts and spars; also for joinery, as it stands and glues well, and shrinks less than pine or fir. But it buckles and expands very much when cut into narrow strips for inside mouldings. Its weight is 35–40 lb. a cub. ft.; cohesive force, 9600–10,960 lb. a sq. in. (See Resins, p. 1666.)

Larch [**American Black**], **Tamarak, or Hackmatack** (*Larix pendula*).—This tree ranges from Newfoundland to Virginia, reaching 80–100 ft. high, and 2–3 ft. diam. The wood is said to nearly equal that of the European species.

Larch [**Common or European**] (*L. europæa*).—This species is a native of the Swiss and Italian Alps, Germany, and Siberia, but not of the Pyrenees nor of Spain. The Italian is most esteemed, and has been considerably planted in England. The tree grows straight and rapidly to 100 ft. high. The wood is extremely durable in all situations, such as posts, sleepers, &c., and is preferable to pine, pinaster or fir for wooden bridges. But it is less buoyant and elastic than Northern Pine, and boards of it are more apt to warp. It burns with difficulty, and makes excellent ship-timber, masts, boats, posts, rails, and furniture. It is peculiarly adapted for staircases, doors, and shutters. It is more difficult to work than Northern Pine, but makes a good surface, and takes oil or varnish better than oak. The liability to warp is said to be obviated by barking the trees while growing in spring, and cutting in the following autumn, or next year; this is also said to prevent dry-rot. The wood weighs 34–36 lb. a cub. ft.; cohesive force, 6000–13,000 lb.; strength, 103; stiffness, 79; toughness, 134. (See Venice Turpentine, p. 1691.)

Lignum-vitæ (*Guaiacum officinale*).—This tree grows chiefly on the S. side of Jamaica, and affords one of the hardest and heaviest woods, extremely useful for the sheaves and blocks of pulleys, for which purpose it should be cut with a band of sap-wood all round, to prevent splitting. Its weight is 73 lb. a cub. ft.; crushing-weight, 9900 lb. The exports of lignum-vitæ from San Domingo in 1880 were:—164 tons to Great Britain, 25 tons to France, 700 tons to Germany, 10 tons to Italy, 239 tons to the United States, 41 tons to the W. Indies; total 1149 tons. The approximate London market value is 4–10*l.* a ton. (See Drugs, p. 816; Resins, p. 1651.)

Locust-tree (*Hymenæa Courbaril*).—This tree is a native of S. America, and is found also in Jamaica. Its wood is hard and tough, and useful for house-building. Its weight is 42 lb. a cub. ft.; crushing-force, 7500 lb.; breaking-weight, 750 lb. (See Jutahy-seca, p. 1666.)

Mahogany (*Swietenia Mahogani*).—This tree is indigenous to the W. Indies and Central America. It is of comparatively rapid growth, reaching maturity in about 200 years, and the trunk exceeding 40–50 ft. long and 6–12 ft. diam. The wood is very durable in the dry, and not liable to worms. Its costliness restricts its use chiefly to furniture; it has been extensively employed in machinery for cotton-mills. It shrinks very little, warps and twists less than any other wood, and glues exceedingly well. It is imported in logs: those from Cuba, Jamaica, San Domingo, known as "Spanish," are about 20–26 in. sq. and 10 ft. long; those from Honduras, 2–4 ft. sq. and 12–14 ft. long. The weight is 35–53 lb. a cub. ft.; the cohesive force is 7560 lb. in Spanish, and 11,475 lb. in Honduras; the strength, stiffness, and toughness are respectively 67, 73, and 61 in Spanish, and 96, 93, and 99 in Honduras.

The tree attains its greatest development and grows most abundantly between 10° N. lat. and the Tropic of Cancer, flourishing best on the higher crests of the hills, and preferring the lighter soils. It is found in abundance along the banks of the Usumacinta, and other large rivers flowing into the Gulf of Mexico, as well as in the larger islands of the W. Indies. British settlements for cutting and shipping the timber were established so long ago as 1638–40, and the right to the territory has been maintained by Great Britain, chiefly on account of the importance of this branch of industry. The cutting-season usually commences about August. It is performed by gangs of men, numbering 20–50, under direction of a "captain" and accompanied by a "huntsman," the duty of the latter being to search out suitable trees, and guide the cutters to them. The felled trees of a season are scattered over a very wide area. All the larger ones are "squared" before being brought away on wheeled trucks along the forest-roads made for the purpose. By March–April, felling and trimming are completed; the dry season by that time permits the trucks to be wheeled to the river-banks. A gang of 40 men work 6 trucks, each requiring 7 pair of oxen and 2 drivers. Arrived at the river, the logs, duly initialed, are thrown into the stream; the rainy season follows in May–June, and the rising current carries them seawards, guided by men following in canoes. A boom at the river-mouth stops the timber, and enables each owner to identify his property. They are then made up into rafts, and taken to the wharves, for a final trimming before shipment. The cutters often continue their operations far into the interior, and over the borders into Guatemala and Yucatan.

The exports of mahogany from British Honduras were 1,821,307 ft. in 1876, 3,080,807 in 1877, 3,146,582 in 1878. San Domingo exported in 1880: 18,000 ft. to Great Britain, 62,400 to France, 24,200 to Germany, 58,500 to Italy, 86,650 to Spain, 104,000 to the W. Indies; total, 353,750 ft. The approximate London market values are:—Cuba, 5–9*d.* a ft.; San Domingo, 5–9*d.*; Mexican, 4–5*d.*; Tobasco, 4½–6*d.*; Honduras, 4–5½*d.* (See Mahogany-gum, p. 1673.)

Mahogany [African] (*S. senegalensis*).—This hard and durable wood is brought from Sierra Leone, and is much used for purposes requiring strength, hardness, and durability. But it is very liable to premature decay, if the heart is exposed in felling or trimming.

Mahogany [E. Indian].—Two species of *Swietenia* are indigenous to the E. Indies:—*S. febrifuga* is a very large tree of the mountains of Central Hindostan; the wood is less beautiful than true mahogany, but much harder, heavier, and more durable, being considered the most lasting timber in India. *S. chloroxylon* is found chiefly in the Circar mountains, and attains smaller dimensions; the wood more resembles box.

Mango (*Mangifera indica*).—This tree grows abundantly in India, where numerous varieties are cultivated, as also in Mauritius, Brazil, and in other tropical climates. Its wood is generally coarse and open-grained, but is excellent for common doors and door-posts when well seasoned; it is light and strong, but liable to snap; it is durable in the dry, but decays rapidly when exposed to weather or water, and is much attacked by worms and ants. Its weight is 41 lb. a cub. ft.; cohesive force, 7700 lb.; breaking-weight, 560 lb. (See Resins, p. 1673.)

Maple (*Acer saccharinum*).—The sugar-maple (see pp. 1902–3) is liable to a peculiarity of growth, which gives the wood a knotted structure, whence it is called "bird's-eye maple." The cause of this structure has never been satisfactorily explained. The handsome appearance thus given to the wood is the reason of its value in furniture and cabinet-making.

Miro (*Podocarpus ferruginea*).—This is a New Zealand tree, giving brownish wood 20–30 ft. long and 15–30 in. sq., useful for internal carpentry and joinery, and weighing 46 lb. a cub. ft.

Mora (*Mora excelsa*).—This tree is a native of British Guiana and Trinidad, growing luxuriantly on sand-reefs and barren clays of the coast regions, reaching 130–150 ft. high, and squaring 18–20 in. Its wood is extremely tough, close, and cross-grained, being one of the most difficult to split. It is one of the eight first-class woods at Lloyd's, making admirable keels, timbers, beams, and knees, and in most respects superior to oak. Its weight is 57 lb. a cub. ft.; crushing-force, 10,000 lb., breaking-weight, 1212 lb.

Mutti (*Terminalia coriacea*).—This is a common tree of Central and S. India. Its wood is hard, heavy, tough, fibrous, close-grained, rather difficult to work, unaffected by white ants, and considered extremely durable. It is used for beams and telegraph-posts. Its weight is 60 lb. a cub. ft.; breaking-weight, 860 lb.

Nan-mu (*Persea Nanmu*).—That portion of the Chinese province of Yunnan which lies between 25° and 26° N. lat. produces the famous *nan-mu* tree, which is highly esteemed by the Chinese for building and coffins, on account of its durability and pleasant odour. It is imported into Shanghai in planks measuring 8 ft. long and 13–14 in. diam., for which the highest price is 200 *dol.* (of 4*s.* 2*d.*) a plank.

Naugiia.—This tree is generally found in the Pacific Islands on desert shores, or on the brinks of lagoons, where its roots are bathed by the tide. Its wood has great weight, intense hardness, and closeness of grain. It is considered a valuable substitute for box for wood-engraving (see p. 1610). Blocks 18 in. diam. are common.

Neem (*Melia Azadirachta*).—This is a common, hardy, and quick-growing Indian tree, reaching 40–50 ft. high, and 20–24 in. diam. The trunk and branches are cut into short, thick planks, much used for lintels of doors and windows. The wood is hard and durable, but attacked by insects. Its fragrant odour makes it in request by natives for doors and door-frames. It is difficult to work, takes a fine polish, and is good for joinery where strength is not demanded; but becomes brittle and liable to snap when dry. Its weight is 51 lb. a cub. ft.; cohesive force, 6940 lb.; breaking-weight, 600 lb. (See Oils—Margosa, p. 1395.)

Oak (*Quercus spp.*).—The most common British oak is *Q. pedunculata*, found throughout Europe from Sweden to the Mediterranean, and in N. Africa and Asia. Its wood is tolerably straight and fine in the grain, and generally free from knots. It splits freely, makes good laths for plasterers and slaters, and is esteemed the best kind for joists, rafters, and other purposes where a stiff, straight wood is desirable. The "durmast" oak (*Q. sessiliflora*) has the same range as the preceding, but predominates in the German forests. Its wood is heavier, harder, and more elastic; liable to warp, and difficult to split. Both are equally valuable in ship-building. Quantities of oak timber are shipped from Norway, Holland, and the Baltic ports, but are inferior to English-grown for ship-building, though useful for other purposes.

Of American oaks, the most important are as follows. The chestnut-leaved (*Q. prinos*) gives a coarse-grained wood, very serviceable for wheel-carriages. The red (*Q. rubra*) in Canada and the Alleghanies, affords a light, spongy wood, useful for staves. The wood of the white oak (*Q. alba*), ranging from Canada to Carolina, is tough, pliable, and durable, being the best of the American kinds, but less durable than British. It is exported from Canada to Europe as "American oak." The iron or post oak (*Q. obtusiloba*), found in the forests of Maryland and Virginia, is frequently called the "box white oak," and chiefly used for posts and fencing. The live oak (*Q. virens*) is the best American ship-building kind, inhabiting the Virginian coast.

Oak warps, twists, and shrinks much in drying. Its weight is 37–68 lb. a cub. ft., according to the kind; cohesive force, 7850–17,892 lb. It is valuable for all situations when it is exposed to the weather, and where its warping and flexibility are not objectionable. Quebec oak is worth about 4*l.* 10*s.*–7*l.* a load; Dantzic and Memel, 3*l.* 10*s.*–5*l.* (See Acorn-oil, p. 1415; Cork, pp. 722–9; Valonia, pp. 1992–3; Oak-barks, pp. 1987–8.)

Oak [African], African Teak, or Turtosa (*Oldfieldia africana*).—This important W. African timber has lately been largely imported from Sierra Leone as a substitute for oak and teak. Though stronger than these, its great weight precludes its general use; but it is valuable for certain parts of ships, as beams, keelsons, waterways, and it will stand much heat in the wake of steamer fires, decaying rapidly, however, in confined situations. It warps in planks, swells with wet, and splits in drying again; it is not proof against insects. Its weight is 58–61 lb. a cub. ft.; cohesive force, 17,000–21,000 lb.

Oak [Australian].—Two hard-wooded trees of Australia are the forest-oak (*Casuarina torulosa*) and the forest swamp-oak (*C. paludosa*). They reach 40–60 ft. high and 12–30 in. diam., and are used in house-building, mainly for shingles, as they split almost as neatly as slate. They weigh 50 lb. a cub. ft.; crushing-force, 5500 lb.; breaking-weight, 700 lb.

The she-oak (*C. quadrivalvis*) and he-oak (*C. suberosa*) of Tasmania are used mostly for ornamental purposes.

Pai-ch'ha (*Euonymus sp.*).—The wood of this tree has been alluded to (p. 1610) as a substitute for box-wood, being extensively produced in China, and largely used at Ningpo and other places for wood-carving. It is very white, of fine grain, cuts easily, and is well suited for carved frames, cabinets, &c.; but it is not at all likely to supersede box-wood, though well fitted for coarser work.

Pear (*Pyrus communis*).—Pear-tree wood is one of the heaviest and hardest of the timbers indigenous to Britain. It has a compact fine grain, and takes a high polish; it is in great request by millwrights in France for making wheel-cogs, rollers, cylinders, blocks, &c., and is preferred before all others for the screws of wine-presses. It ranks second to box for wood-engraving and turnery.

Persimmon (*Diospyros virginiana*).—The Virginian date-palm or persimmon is a native of the United States, growing 50–60 ft. high and 1½ ft. diam. Its heart-wood is brown, hard, and elastic, but liable to split; it has been with some success introduced into England as a substitute for boxwood in shuttle-making and wood-engraving.

Pine [Black] or Matai (*Podocarpus spicata*).—This New Zealand timber is much more durable than Miro (p. 2017), and is used for all purposes where strength and solidity are required. Its weight is 40 lb. a cub. ft.; breaking-weight, 420–800 lb.

Pine [Cluster] or Pinaster (*Pinus Pinaster*).—This pine inhabits the rocky mountains of Europe, and is cultivated in English plantations; it reaches 50–60 and even 70 ft. in height. It likes deep dry sand, or sandy loam in a dry bottom; but avoids all calcareous soils. The wood is said to be more durable in water than in air. It is much used in France for shipping-packages, piles and props in ship-building, common carpentry, and fuel. It weighs 25½ lb. a cub. ft.

Pine [Huon] (*Dacrydium Franklinii*).—This tree is said to be abundant in portions of S.-W. Tasmania, growing 50–100 ft. high and 3–8 ft. diam. The wood is clean and fine-grained, being closer and more durable than American White Pine, and can be had in logs 12–20 ft. long and 2 ft. sq. Its weight is 40 lb. a cub. ft.

Pine [Moreton Bay] (*Araucaria Cunninghami*).—This abundant Queensland tree grows over 150 ft. high and 5 ft. diam., giving spars 80–100 ft. long. Its wood is straight-grained, tough, and excellent for joinery; but is not so durable as Yellow Pine, and is liable to attacks of sea-worms and white ants. It is used for flooring and general carpentry, and for shingles; it holds nails and screws well. Its weight is 45 lb. a cub. ft.

Pine [Norfolk Island] (*A. excelsa*).—This tree inhabits Norfolk Island and Australia, growing 200–250 ft. high and 10–12 ft. diam. Its wood is tough, close-grained, and very durable for indoor work.

Pine [Northern], or Red, Yellow, Scotch, Memel, Riga, or Dantzic Fir (*Pinus sylvestris*).—This tree forms with the spruce fir the great forests of Scandinavia and Russia, and attains considerable size in the highlands of Scotland. The logs shipped from Stettin reach 18–20 in. sq.; those from Dantzic, 14–16 in. and even 21 in. sq., and up to 40–60 ft. long; from Memel, up to 13 in. sq., and 35 ft. long; from Riga, 12 in. sq. and 40 ft. long, and spars 18–25 in. diam. and 70–80 ft. long; Swedish and Norwegian, up to 12 in. sq. It comes also in planks (11 in. wide), deals (9 in.), and battens (7 in.). The best are Christiania yellow deals, but contain much sap; Stockholm and Gefle are more disposed to warp; Gottenburg are strong, but bad for joinery; Archangel and Onega are good for joinery, but not durable in damp; Wiborg are the best Russian, but inclined to sap; Petersburg and Narva yellow are inferior to Archangel. Well-seasoned pine is almost as durable as oak. Its lightness and stiffness render it the best timber for beams, girders, joists, rafters, and framing; it is much used for masts; and for joinery is superior to oak on all scores. The hardest comes from the coldest districts. The cohesive force is 7000–14,000 lb. per sq. in.; weight, 29–40 lb. per cub. ft.; strength, 80; stiffness, 114; toughness, 56. (See Rosin, p. 1680; Pitch, pp. 1678–9; Pine-oils, p. 1408; Turpentine-oils, p. 1431; Thus, p. 1684; Tars, p. 1683; Turpentine, p. 1687.)

Pine [Pitch] (*P. rigida* [*resinosa*]).—This species is found throughout Canada and the United States, most abundantly along the Atlantic coast. The wood is heavy, close-grained, elastic, and durable, but very brittle when old or dry, and difficult to plane. The heart-wood is good against alternate damp and dryness, but inferior to White Pine underground. Its weight is 41 lb. per cub. ft.; cohesive force, 9796 lb. per sq. in.; stiffness, 73; strength, 82; toughness, 92.

Pine [Red, Norway, or Yellow] (*P. rubra* [*resinosa*]).—This tree grows on dry stony soils in Canada, Nova Scotia, and the N. United States, reaching 60–70 ft. high, and 15–25 in. diam. at 5 ft. above ground. The wood weighs 37 lb. per cub. ft.; it is much esteemed in Canada for strength and durability, and, though inferior in these respects to Northern Pine, is preferred by English shipwrights for planks and spars, being soft, pliant, and easily worked.

Pine [Red] or Rimu (*Dacrydium cupressinum*).—This New Zealand wood runs 45 ft. long, and up to 30 in. sq., and is much used in house-framing and carpentry, but is not so well adapted to joinery, as it shrinks irregularly. It weighs 40 lb. a cub. ft. (See Rimu-resin, p. 1680.)

Pine [Weymouth or White] (*Pinus strobus*).—This tree inhabits the American continent between 43° and 47° N. lat., occupying almost all soils. The timber is exported in logs over 3 ft. sq. and 30 ft. long; it makes excellent masts; is light, soft, free from knots, easily worked, glues well, and is very durable in dry climates; but is unfit for large timbers, liable to dry-rot, and not durable in damp places, nor does it hold nails well. It is largely employed for wooden houses and timber bridges in America. Its weight is 28¾ lb. per cub. ft.; cohesive force, 11,835 lb.; stiffness, 95; strength, 99; toughness, 103.

Pine [White], or Kahikatea (*Podocarpus dacrydioides*).—This New Zealand timber tree gives wood 40 ft. long and 24–40 in. sq., straight-grained, soft, flexible, warping and shrinking little, and well adapted for flooring and general joinery, though decaying rapidly in damp. Its weight is 30 lb. a cub. ft.; breaking-weight, 620 lb.

Pine [Yellow, Spruce, or Short-leaved] (*Pinus variabilis* and *P. mitis*).—The former species is found from New England to Georgia, the wood being much used for all carpentry, and esteemed for large masts and yards; it is shipped to England from Quebec. The latter is abundant in the Middle States and throughout N. America, reaching 50–60 ft. high and 18 in. diam. It is much used locally for framework: the heart-wood is strong and durable; the sap-wood is very inferior.

Plane (*Platanus orientalis* and *P. occidentalis*).—The first species inhabits the Levant and adjoining countries, growing 60–80 ft. high and up to 8 ft. diam. The wood is more figured than beech, and is used in England for furniture; in Persia, it is applied to carpentry in general.

The second species, sometimes called " water-beech," " button-wood," and " sycamore," is one of the largest N. American trees, reaching 12 ft. diam. on the Ohio and Mississippi, but generally 3–4 ft. The wood is harder than the oriental kind, handsome when cut, works easily, and stands fairly well, but is short-grained and easily broken. It is very durable in water, and preferred in America for quays. Its weight is 40–46 lb. a cub. ft.; cohesive force, 11,000 lb.; strength, 92; stiffness, 78; toughness, 108.

Poon (*Calophyllum Burmanni*).—This tree is abundant in Burma, S. India, and the E. Archipelago. It is tall and straight, and about 6 ft. circ. It is used for the decks, masts, and yards of ships, being strong and light. Its texture is coarse and porous, but uniform: it is easy to saw and work up, holds nails well, but is not durable in damp. Its weight is 40–55 lb. a cub. ft.; cohesive force, 8000–14,700 lb. Another species (*C. angustifolium*) from the Malabar Hills is said to furnish spars.

Poplar (*Populus spp.*).—Five species of poplar are common in England: the white (*P. alba*), the black (*P. nigra*), the grey (*P. canescens*), the aspen or trembling poplar (*P. tremula*), and the Lombardy (*P. dilatata*); and two in America: the Ontario (*P. macrophylla*), and the black Italian (*P. acladesca*). They grow rapidly, and their wood is generally soft and light, proving durable in the dry, and not liable to swell or shrink. It makes good flooring for places subject to little wear, and is slow to burn. It is much used for butchers' trays and other purposes where weight is objectionable. The Lombardy is the lightest and least esteemed, but is proof against mice and insects. The weight is 24–33 lb. a cub. ft.; cohesive force, 4596–6641 lb.; strength, 50–86; stiffness, 44–66; toughness, 57–112. Poplar is one of the best woods for paper-making (see p. 1493). The trees also yield an oil (p. 1427).

Pymma (*Lagerstrœmia reginæ*).—The wood of this abundant Indian tree, particularly in S. India, Burma, and Assam, is used more than any except teak, especially in boat-building, and posts, beams, and planks in house-building. Its weight is 40 lb. a cub. ft.; cohesive force, 13,000–15,000 lb.; breaking-weight, 640 lb.

Pynkado or Ironwood (*Inga xylocarpa*).—This valuable timber tree is found throughout S. India and Burma. Its wood is hard, close-grained, and durable; but it is heavy, not easily worked, and hard to drive nails into. It is much used in bridge-building, posts, piles, and sleepers. Its weight is 58 lb. a cub. ft.; cohesive force, 16,000 lb.; breaking-weight, 800 lb.

Rata (*Metrosideros lucida*).—This tree is indigenous to New Zealand, giving a hard timber 20–25 ft. long and 12–30 in. sq., very dense and solid, weighing 65 lb. a cub. ft.

Rohun (*Soymida febrifuga*).—This large forest tree of Central and S. India affords a close-grained, strong and durable wood, which stands well when underground or buried in masonry, but not so well when exposed to weather. It is useful for palisades, sleepers, and house-work, and is not very difficult to work. Its weight is 66 lb. a cub. ft.; cohesive force, 15,000 lb.; breaking-weight, 1000 lb.

Rosewood.—The term " rosewood " is applied to the timber of a number of trees, but the most important is the Brazilian. This is derived mainly it would seem from *Dalbergia nigra*, though it appears equally probable that several species of *Triptolemœa* and *Machœrium* contribute to the inferior grades imported thence. The wood is valued for cabinet-making purposes. The approximate London market values are 12–25*l.* a ton for Rio, and 10–22*l.* for Bahia.

Sabicu (*Lysiloma Sabicu*).—This tree is indigenous to Cuba, and found growing in the Bahamas, where it has probably been introduced. Its wood is exceedingly hard and durable, and has been much valued for ship-building. It has been imported from the Bahamas in uncertain quantities for the manufacture of shuttles and bobbins for cotton-mills. The exports thence were 167 tons in 1878, and 101 tons in 1879.

Sal or Saul (*Shorea robusta*).—This noble tree is found chiefly along the foot of the Himálayas, and on the Vindhyan Hills near Gaya, the best being obtained from Morung. Its wood is strong, durable, and coarse-grained, with particularly straight and even fibre; it dries very slowly, continuing to shrink years after other woods are dry. It is used chiefly for floor-beams, planks, and roof-trusses, and can be had in lengths of 30–40 ft., and 12–24 in. sq. Its weight is 55–61 lb. a cub. ft.; cohesive force, 11,500 lb.; crushing-force, 8500 lb.; breaking-weight, 881 lb.

Satin-wood.—The satin-wood of the Bahamas is supposed to be the timber of *Maba guianensis*, an almost unknown tree. The Indian kind is derived from *Chloroxylon Swietenia*, a native of Ceylon, the Coromandel coast, and other parts of India. The former comes in square logs or planks 9–20 in. wide; the latter, in circular logs 9–30 in. diam. The chief use of satin-wood is for making the backs of hair- and clothes-brushes, turnery, and veneering. The exports from the Bahamas were 5037 pieces in 1878, and 18,783 in 1879, all to England. The approximate value of San Domingan is 6–18*d.* a ft. The Indian tree yields a gum (see p. 1682).

Sissu or Seesum (*Dalbergia Sissu*).—This tree is met with in many parts of India, being said to attain its greatest size at Chanda. Its wood resembles the finest teak, but is tougher and more elastic. Being usually crooked, it is unsuited for beams, though much used by Bengal ship-builders, and in India generally for joinery and furniture. Its weight is 46½ lb. a cub. ft.; cohesive force, 12,000 lb.; breaking-weight, 700 lb.

Sneezewood or Nies Hout (*Pteroxylon utile*).—This most durable S. African timber, the *oomtata* of the natives, is invaluable for railway-sleepers and piles, being almost imperishable.

Spruce Fir [American Black] (*Abies nigra*).—This tree inhabits Canada and the N. States, being most abundant in cold-bottomed lands in Lower Canada. It reaches 60–70 and even 100 ft. high, but seldom exceeds 24 in. diam. The wood is much used in America for ships' knees, when oak and larch are not obtainable.

Spruce Fir [American White], Epinette, or Sapinette blanche (*A. alba*).—This white-barked fir is a native of high mountainous tracts in the colder parts of N. America, where it grows 40–50 ft. high. The wood is tougher, lighter, less durable, and more liable to twist in drying than white deal, but is occasionally imported in planks and deals. It weighs 29 lb. a cub. ft.; cohesive force, 8000 to 10,000 lb.; strength, 86; stiffness, 72; toughness, 102.

Spruce Fir [Red], or Newfoundland Red Pine (*A. rubra*).—This species grows in Nova Scotia, and about Hudson's Bay, reaching 70–80 ft. high. It is universally preferred in America for ships' yards, and imported into England for the same purpose. It unites in a higher degree all the good qualities of the Black Spruce Fir.

Stringy-bark (*Eucalyptus gigantea*).—This tree affords one of the best building woods of Australia, being cleaner and straighter-grained than most of the other species of *Eucalyptus*. It is hard, heavy, strong, close-grained, and works up well for planking, beams, joists, and flooring, but becomes more difficult to work after it dries, and shrinks considerably in drying. The outer wood is better than the heart. Its weight is 56 lb. a cub. ft.; crushing-force, 6700 lb.; breaking-weight, under 500 lb.

Sycamore or Great Maple (*Acer pseudo-platanus*).—This tree, mis-called "plane" in N. England, is indigenous to mountainous Germany, and very common in England. It thrives well near the sea, is of quick growth, and has a trunk averaging 32 ft. long and 29 in. diam. The wood is durable in the dry, but liable to worms; it is chiefly used for furniture and ornaments. Its weight is 34–42 lb. a cub. ft.; cohesive force, 5000–10,000 lb.; strength, 81; stiffness, 59; toughness, 111.

Tamanu (*Calophyllum sp.*).—This valuable tree of the S. Sea Islands is becoming scarce. It sometimes reaches 200 ft. high and 20 ft. diam. Its timber is very useful for ship-building and ornamental purposes, and is like the best Spanish mahogany. It yields an oil (see Dilo, p. 1387), and a resin (see Tamanu, p. 1683).

Tanakaha (*Podocarpus asplenifolius*).—This is a light-coloured New Zealand wood, close and straight in the grain, and running 20–40 ft. long and 10–16 in. sq.

Teak (*Tectona grandis*).—This tall, straight, rapidly-growing tree inhabits the dry elevated districts of the Malabar and Coromandel coasts of India, as well as Burma, Pegu, Java, and Ceylon. Its wood is light, easily worked, strong, and durable; it is the best for carpentry where strength and durability are required, and is considered foremost for ship-building. The Moulmein product is much superior to the Malabar, being lighter, more flexible, and freer from knots. The Vindhyan excels that of Pegu in strength, and in beauty for cabinet-making. The Johore is the heaviest and strongest, and is well suited for sleepers, beams, and piles. It is unrivalled for resisting worms and ants. Its weight is 45–62 lb. a cub. ft.; cohesive force, 13,000–15,000 lb.; strength, 109; stiffness, 126; toughness, 94. The quantities of teak brought down from British Burma were 46,431 tons in 1876–7, 39,081 in 1877–8, 22,763 in 1878–9, 17,585 in 1879–80. The approximate market value is 8-15*l.* a load. (See Tar, p. 1684.)

Toon, or Chittagong wood (*Cedrela Toona*).—This tree is a native of Bengal and other parts of India, where it is highly esteemed for joinery and furniture, measuring sometimes 4 ft. diam., and somewhat resembling mahogany. Its weight is 35 lb. a cub. ft.; cohesive force, 4992 lb.; breaking-weight, 560 lb.

Totara (*Podocarpus Totara*).—This tree is fairly abundant in the N. and S. islands of New Zealand, reaching 80 ft. high and 2½–3½ ft. diam. Its wood is easily worked, straight- and even-grained, warps little, and splits very clean and free; but it is brittle, apt to shrink if not well seasoned, and subject to decay in the heart. It is used generally for joinery and house-building. Its weight is 40 lb.; breaking-weight, 570 lb.

Walnut (*Juglans regia*).—The walnut-tree is a native of Greece, Asia Minor, Persia, along the Hindu Kush to the Himálayas, Kashmir, Kumaon, Nepal, and China, and is cultivated in Europe up to 55° N. lat., thriving best in dry, deep, strong loam. It reaches 60 ft. high and 30–40 in. diam. The young wood is inferior; it is in best condition at about 50–60 years. Its scarcity excludes it from building application, but its beauty, durability, toughness, and other good qualities render it esteemed for cabinet-making and gun-stocks. Its weight is 40–48 lb. a cub. ft.; cohesive force, 5360–8130 lb.; strength, 74; stiffness, 49; toughness, 111; all taken on a green sample.

Of the walnut-burrs (or *loupes*), for which the Caucasus was once famous, 90 per cent. now come from Persia. The walnut forests along the Black Sea, which give excellent material for gun-stocks, do not produce burrs, which occur only in the drier climates of Georgia, Daghestan, and Persia. Italian walnut is worth 4–5½*d.* a ft. Poti exported 35,413 *poods* (of 36 lb.) in 1877–8. Trebizonde, in 1879, sent 32 cwt. to Turkey, 2765 to Great Britain, 12,179 to France; total value, 29,956*l.*; in 1880, 1832 cwt. to Great Britain, and 4137 to France; total value, 11,938*l.* Samsoun exported 1000 cwt., 2000*l.*, in 1880. Ancona exported 131,209 planks, value 37,895*l.*, to Great Britain in 1878. (See Nuts, p. 1360; Oils, p. 1413.)

Walnut [Black Virginia] (*J. nigra*).—This is a large tree ranging from Pennsylvania to Florida; the wood is heavier, stronger, and more durable than European walnut, and is well adapted for naval purposes, being free from worm attacks in warm latitudes. It is extensively used in America for various purposes, especially cabinet-making.

Willow (*Salix spp.*).—The wood of the willow is soft, smooth, and light, and adapted to many purposes. It is extensively used for the blades of cricket-bats, for building fast-sailing sloops, and in hat-making (see pp. 1102–27), and its charcoal is used in gunpowder-making (see p. 882).

Yellow-wood or Geel Hout (*Taxus elongatus*).—This is one of the largest trees of the Cape Colony, reaching 6 ft. diam. Its wood is extensively used in building, though it warps much in seasoning, and will not bear exposure.

Yew (*T. baccata*).—This long-lived shrubby tree inhabits Europe, N. America, and Japan, being found in most parts of Europe at 1000–4000 ft., and frequently on the Apennines, Alps, and Pyrenees, and in Greece, Spain, and Great Britain. The stem is short, but reaches a great diameter (up to 20 ft.). The wood is exceedingly durable in flood-gates, and beautiful for cabinet-making. Its weight is 41–42 lb. a cub. ft.; cohesive force, 8000 lb.

Commerce.—Our imports of wood and timber in 1880 were as follows:—Hewn Fir: From Norway, 338,943 loads, 506,142*l.*; Russia, 331,012 loads, 630,894*l.*; Sweden, 308,702 loads, 527,163*l.*; France, 293,117 loads, 295,805*l.*; British N. America, 262,663 loads, 1,012,210*l.*; Germany, 225,964 loads, 520,949*l.*; United States, 137,017 loads, 440,262*l.*; other countries, 13,191 loads, 13,055*l.*; total, 1,910,609 loads, 3,946,480*l.*

Hewn Oak: From Germany, 46,276 loads, 225,234*l.*; British N. America, 44,888 loads, 277,945*l.*; Russia, 3285 loads, 35,160*l.*; United States, 1725 loads, 12,672*l.*; France, 1206 loads, 5554*l.*; Austria, 959 loads, 8657*l.*; other countries, 160 loads, 1896*l.*; total, 98,499 loads, 567,118*l.*

Hewn Teak: From Bengal and Burma, 33,211 loads, 401,361*l.*; other countries, 652 loads, 9073*l.*; total, 33,863 loads, 410,434*l.*

Hewn, unenumerated: From British N. America, 65,512 loads, 249,180*l.*; Norway, 5576 loads, 10,108*l.*; British Guiana, 4938 loads, 37,289*l.*; Sweden, 4675 loads, 8103*l.*; other countries, 6869 loads, 23,437*l.*; total, 87,570 loads, 328,117*l.*

Sawn or Split, Planed or Dressed Fir: From British N. America, 1,158,653 loads, 3,037,481*l.*; Sweden, 1,066,394 loads, 2,833,692*l.*; Russia, 966,513 loads, 2,508,514*l.*; Norway, 366,400 loads, 1,002,885*l.*; United States, 171,049 loads, 522,591*l.*; Germany, 63,973 loads, 165,876*l.*; other countries, 2860 loads, 4217*l.*; total, 3,795,842 loads, 10,075,256*l.*

Ditto, unenumerated: From Sweden, 138,619 loads, 176,481*l.*; Russia, 95,505 loads, 145,364*l.*; Norway, 38,760 loads, 46,626*l.*; Holland, 15,866 loads, 75,079*l.*; British N. America, 14,367 loads, 44,504*l.*; United States, 10,626 loads, 61,618*l.*; Germany, 5367 loads, 14,270*l.*; other countries, 1797 loads, 6750*l.*; total, 320,907 loads, 570,692*l.*

Staves: From Norway, 30,283 loads, 75,871*l.*; Germany, 21,344 loads, 178,461*l.*; Russia, 16,592 loads, 43,752*l.*; Sweden, 15,670 loads, 36,476*l.*; United States, 11,590 loads, 75,040*l.*; British N. America, 6493 loads, 42,041*l.*; Austria, 1545 loads, 18,056*l.*; other countries, 19 loads, 150*l.*; total, 103,536 loads, 469,847*l.*

Furniture hardwoods and veneers: Mahogany: From Mexico, 24,096 tons, 218,604*l.*; British Honduras, 6132 tons, 41,310*l.*; Spanish W. Indies, 5099 tons, 44,748*l.*; Central America, 3295 tons, 28,384*l.*; Hayti and San Domingo, 1290 tons, 13,613*l.*; other countries, 1437 tons, 12,206*l.*; total, 41,349 tons, 358,865*l.*

Ditto, unenumerated: From United States, 11,389 tons, 96,607*l.*; British N. America, 4328 tons, 33,046*l.*; British W. Indies, 2898 tons, 22,734*l.*; Turkey, 2712 tons, 34,689*l.*; France, 2294 tons, 47,296*l.*; Spanish W. Indies, 2288 tons, 19,929*l.*; Italy, 1769 tons, 12,054*l.*; W. Africa, 1733 tons, 14,872*l.*; Germany, 1219 tons, 11,849*l.*; Australia, 1194 tons, 9652*l.*; Brazil, 1135 tons, 16,979*l.*; Central America, 1107 tons, 8464*l.*; other countries, 3780 tons, 36,543*l.*; total, 37,846 tons, 364,714*l.*

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VARNISH (Fr., *Vernis*; Ger., *Firniss*).

A "varnish" is any substance which, when applied to the surface of an object, leaves on that surface a continuous, smooth, impervious coating, whose functions are:—(1) To increase the lustre and polish of that surface, and, by obliterating its asperities and filling up its pores, prevent its easy soiling, and facilitate washing (e. g. paint, *papier-maché*, glazing of pottery, &c.); (2) by its high refractive power to increase the transparency of surfaces which are by their porosity rendered too opaque, and thus to bring into view any "grain" or interior structure which it is desirable to show up (e. g. oiling, varnishing, or waxing wood, transparent blinds, tracing-paper, &c.); (3) by its insolubility in water and oils, to protect perishable structures from the effect of damp, decay, mould, &c., metals from rust and corrosion by acids, and porous bodies from grease-spots; (4) by hardening the surface of softer objects to save them from abrasion (e. g. varnishing deal and other soft woods, pasteboard, book-covers, leather, &c.).

Varnishes group themselves naturally into 5 well-marked divisions:—I. Natural lacquers of the Indian and Chinese type, produced by several genera of trees of the natural order *Anacardiaceæ*. These are liquid at first, but dry slowly (by oxidation?) on exposure to the air (see p. 1692). II. Drying oils, which indurate or resinify by oxidation in the air, either in their natural state, or made more drying by various chemical treatment. III. Oil-varnishes proper, composed of an intimate combination of a drying oil with a fused resin, and hardening by the oxidation of the oil. These may either be applied in their undiluted state, or may be thinned with essential oils, or other liquid volatile hydrocarbons, to such a consistence as will enable them to be applied with a brush. IV. Varnishes composed of a volatile liquid holding in solution resins, or gums, or other solid amorphous (non-crystalline) substances, which, on the evaporation of the solvent, are left behind as a vitreous coating on the surface varnished. V. Glazes and enamels, applied to the work in a solid state, in powder or otherwise, and attached to its surface by raising it to a heat sufficient to melt the glaze, &c.; or formed by the fused surface of the object itself, when vitrified at a high temperature by appropriate fluxes (e. g. etching-ground, glazing of porcelain and pottery, salt-glazed stoneware, &c., the last two not coming within the scope of this article, but described on pp. 1571–2, 1594–6).

Materials used in Varnish-making.—These may be conveniently arranged under 6 separate heads, according to the part they play in the finished varnish:—(1) The drying oils. (2) Those resins which have sufficient hardness and transparency for the purpose, and whose melting-point is high enough to prevent their becoming softened and sticky in summer, in heated rooms, or by the heat of the hand. (3) "Colloid" bodies soluble in water, such as albumen, gum arabic, dextrine, gelatine, &c. (4) "Solvents," i. e. volatile liquids used to dissolve resins or gums, or to dilute oil-varnishes, but which evaporate entirely during the drying of the varnish, thus contributing nothing to the thickness of the coating. (5) "Tougheners," or substances added to varnishes, of Class IV., to make them more flexible, and less liable to crack, or be scratched. (6) "Driers," which, by giving up oxygen, or by acting as "carriers" of atmospheric oxygen, hasten the hardening of the drying oils. (7) Soluble transparent colouring matters, resinous or otherwise, used in lacquers and changing-varnishes.

Drying-oils.—The principal oils in use at the present day for paints and varnishes are those of the poppy, walnut, hemp-seed, and linseed.

Poppy-oil (p. 1409).—The chief use of this oil in England seems to be for the grinding of the fine colours used by artists in picture-painting. Being generally considered (and probably correctly so) a much slower drier than either linseed- or walnut-oil (commonly called "nut-oil"), it is seldom if ever used in varnish-making.

Walnut-oil or Nut-oil (p. 1413).—With regard to the drying powers of this oil, some authorities place it above linseed-oil, and others below it, whilst most of the older writers considered it as very little, if at all, inferior. We are inclined, from all accounts, to agree with the last-mentioned opinion, although almost all that comes into the English market is far inferior to linseed-oil. The cause may be that the palest oil has been chosen in the Continental market as the best as well as the dearest, but in ignorance of the fact that the best salad oils are generally the worst driers.

Hempseed-oil (p. 1391).—This is generally supposed to be about equal to linseed- and walnut-oils in drying quality. It is said to make a very bad-smelling and deep-coloured boiled oil; but seems, from all accounts, to be much used in E. and N. Europe for paints and varnishes, though very little, if at all, in England.

Linseed-oil (p. 1393).—This oil, which from its high drying property, its cheapness, its steady supply, and its great constancy of quality (when free from any adulteration with non-drying oils), is universally employed in W. Europe for oil-varnishes, and boiled oil for painting, japanning, floor-cloth, and all other purposes where a strongly-drying oil is required; it is also the one prescribed in the oldest of all known recipes for varnish and for oil-painting.

All oil to be used in oil-varnishes or for boiled oil should be chosen as new, sweet, and free from rancidity as possible, and should be at once clarified and allowed to settle for a few months before being used, so as to deposit impurities, "mucosities," and the substances (if any) used in clarifying it, and, when clear, should be decanted from the dregs, and stored for use in slate or galvanized-iron tanks.

Many methods have been used for the clarification of oils (see p. 1459), to rid them of the gummy and mucous matters, water, saline substances, &c., derived from the seed during expression, and which, besides making the oil turbid, induce a kind of rancid fermentation, and much impair the keeping quality of the oil, and hinder its drying. The simplest of all these processes consists in heating the oil slowly up to 300° (572° F.) either alone or with the addition of 1–5 parts in 1000 of either caustic lime, carbonate of lime, calcined magnesia, or carbonate of magnesia, and keeping it at that temperature for one or two hours, and then allowing it to cool uncovered and undisturbed. The oil should then be transferred to a settling-tank to deposit and clarify.

When thus freed from the impurities arising from the seed, the oil will not so easily get rancid, and will improve by keeping, becoming more pale, limpid, transparent, and drying, in proportion to its age. All oils prescribed in the recipes for oil-varnishes in the course of this article will be supposed to have been clarified by this or some other process.

Resins.—In addition to what has been said under this head (pp. 1621–95), the following may be enumerated with especial reference to their use in varnishes.

Oil-varnish Resins.—(1) Amber (p. 1628) is the hardest and most difficult to fuse, but gives the most durable and resisting oil-varnish, of dark colour unfortunately. (2) The true copals (p. 1640) make the finest of all the oil-varnishes, nearly as hard and durable as amber-varnish, and much paler in colour and more quick-drying. (3) The pseudo-copals,—kauri (p. 1666), and hard and soft Manilla (p. 1678), give varnish inferior to the true copals, but more easily made. (4) Sandarach (p. 1681), is almost unknown as an oil-varnish resin at the present day, its use being entirely confined to spirit-varnishes; it is, however, equal to most of the true copals for varnish-making in point of hardness and general qualities, excepting colour. (5) The resins of the conifers, constituting the "rosin" of commerce (p. 1680), make poor weak varnishes, only fit for the commonest purposes.

All the above oil-varnish resins, with the exception of group 5, are quite insoluble in linseed-oil, turps, and other essential oils, benzol and its homologues, petroleum, chloroform, &c., until they have undergone destructive fusion at nearly red-heat, after which they dissolve freely in all.

Essence-varnish resins.—(1) All the copals, amber, sandarach, and the pseudo-copals, after fusion. (2) All the dammars (p. 1644), without previous fusion. (3) Mastic and other resins from species of *Pistacia* (pp. 1673, 1687). (4) Coniferous resins and turpentines. (5) The resins of copaiba and gurjun balsams (pp. 1639, 1651). These resins are soluble in essential oils and other hydrocarbons, and in ether, chloroform, &c., forming Classes A and B of Div. IV., called oleo-resinous or essential-oil varnishes, and ether varnishes.

Spirit-varnish resins.—(1) Lac (p. 1668), which stands at the head of varnish-making resins, having no rival amongst them for hardness and toughness. (2) Certain true copals from Africa are entirely soluble in strong alcohol (methylated spirit). (3) Soft Manilla copal (so called). (4) Sandarach, which has for several hundred years been the stock resin for pale spirit-varnishes, being the only pale dry resin then known soluble in spirit. (5) The turpentines, rosins, and naturally-dried turpentines ("thus") of nearly all the pines, firs, and larches. (6) The *Pistacia* resins.

Many of the copals and other resins, which are not entirely soluble in strong alcohol, dissolve completely in a mixture of methylated spirit with some simple hydrocarbon, e.g. benzol, toluol, turps, lavender-oil, &c., or with chloroform, acetic ether, or acetone, making excellent varnishes.

To the above resins, may be added a few others, which are only chosen for their colour in lacquers and "changing-varnishes," or to give a more pleasant odour to furniture and fancy varnishes. They are:—

Gamboge (pp. 1551, 1650–1), a bright-yellow gum-resin, yielding its colour to alcohol, turps, ether, benzol, &c., gives the brightest of all yellows for pale brass lacquers.

Dragon's-blood (p. 1648), yields a rich orange-red coloured resin to alcohol, ether, chloroform, and benzol, but not to turps nor petroleum.

Gum Acaroides and Black-boy gum (p. 1693) in solution vary in colour from brownish-yellow to brownish-red. They are insoluble in chloroform, benzol, turps, and petroleum. They furnish resins hard enough to be used alone as spirit lacquers, for deep brass or bronze.

Aloes (p. 791–3). The inspissated juice of various species of *Aloë* was much used in the 17th and previous centuries, for colouring oil-lacquers and changing-varnishes, used over tinfoil to imitate gilding in decoration, and is still used in pale brass spirit-lacquers.

Benzoin (p. 1637). That which is of the greyest colour, and containing most and largest white tears, will usually give the palest solution in spirit. It is sometimes used alone as a last coat or "finish" to French-polish and other spirit-varnishes, to give scent and brilliancy. It is soluble in all the solvents commonly used, excepting benzol and petroleum, which only dissolve a portion of it.

Asphaltum is of such very important use in all black oil-varnishes and japans, as also in etching-grounds and some black essence-varnishes, and is so liable to adulteration, that great care is requisite in choosing it of good quality. It should be entirely (excepting perhaps 4–5 per cent. of earthy impurities) soluble in chloroform, toluol and its higher homologues, rosin-spirit, and turps, and quite insoluble in alcohol, and in a mixture of equal parts of alcohol and chloroform. It should break with a conchoidal fracture and brilliant resinous lustre; the rubbed surfaces and angles are usually covered with a bright-brown powder. It should not flow like wood-pitch when laid by for some time on a horizontal surface, and an angular fragment or thin chip should retain its shape and the sharpness of its angles in boiling water, and only begin to flow at a temperature of 150°–200° (300°–400° F.). When adulterated with coal-pitch, it is much less brilliant on the surface of fracture, which then has a lustre rather adamantine or sub-metallic than resinous, and when fused, has a granular, pasty appearance and feel, instead of being smooth and homogeneous, and will not draw out into even and transparent brown threads like pure asphaltum. This is the most important adulteration, a small percentage of coal-pitch spoiling it utterly for varnish-making, or etching-grounds. (See Asphalt, p. 341.)

Gums, &c., used in water-varnishes and glazes.—(1) Gelatine (pp. 522–4, 620–2). That used for glazing paper and fancy articles of cardboard, light wood, &c., should be of the best quality, particularly in damp climates. It should especially be free from saline impurities, and overboiled portions, which make it liable to get damp and sticky in wet weather, besides diminishing its lustre. Parchment-size (p. 622) is one of the best. Of commercial glues and gelatines, those should be chosen which give the stiffest jelly with the same proportion of water.

(2) Gluten of cereals, especially wheat (see pp. 622–3, 1821–9), after washing away the starch, has been used as a varnish when dissolved in weak alcohol, in which a considerable portion is said to be soluble.

(3) Albumen, Caseine, Legumine, &c.—The first two are regularly manufactured as articles of commerce (see pp. 191–2, 1304). Egg-albumen is the cleanest and palest, but requires long-continued "whipping" to thoroughly break down its organized structure, before its glairy character is removed, and the albumen is fit for varnishes. Blood albumen is now manufactured of such excellent quality as to supersede that from eggs wherever large quantities are wanted.

Caseine is also made on a commercial scale, and seems to be used in some of the foreign boot and leather varnishes. Legumine, which might easily be obtained in large quantities from any cheap beans, tares, or other leguminous seeds, has never been used to any important extent in water-varnishes.

(4) Gum arabic and the allied acacia gums (p. 1630) are not so much used pure in glazes and varnishes as gelatine, but enter into and give gloss to many liquid preparations, such as blacking, ink, boot-glosses and varnishes, kid-revivers, &c., and form the vehicle or cementing material for artists' water-colours.

5. Lac, dissolved in water by means of borax or alkaline carbonates, also makes a good water-varnish, and the solution forms the principal ingredient in many of the best boot- and leather-varnishes, and in waterproof inks.

Volatile solvents.—Turps (essential oil or spirit of turpentine,* pp. 1431, 1686) is the volatile oil, obtained by distillation from the turpentines of the coniferous trees, of which it constitutes 10–35 per cent. It is at the present day found very pure in commerce, being at a low price; but when the price becomes high, adulteration with petroleum and rosin-spirit is much practised.

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* The word "turpentine" has been of late years very generally but most erroneously used to signify the *essential oil* or *spirit* of turpentine, as well as the turpentine itself. It will never be so used in this article, but will be strictly confined to its real meaning, i.e. the natural oleo-resin, as produced by the various coniferous trees, and *Pistacia terebinthus.* The *spirit* of turpentine will be designated by the word "turps", which is in general use, has only one meaning, and has the advantage of brevity.

Turps is the most important solvent used in varnishes of the third and fourth divisions, and every care should be taken to choose it of the best quality, i. e. free from adulteration, and new, or freshly-distilled. Old turps should never be used, especially if it shows the least thickening or "fatness," for although such "fat" turps unquestionably helps oil-varnishes to dry quickly (owing to the oxygen it has absorbed from the air, and holds in very loose combination), and is therefore, and for the brilliancy it gives them, sometimes preferred by varnish-makers of the old school, yet it only does so at great cost of hardness and durability.

Turps is also the solvent chiefly used in varnishes belonging to Class A of the fourth division, and here it is especially desirable that it should be new, or the varnish may remain for days before it is dry enough to be touched with safety, catching dust all the time.

Petroleum, Benzoline, Benzine-spirit, Gazoline, &c. (pp. 1433, 1509). The different substances composing the liquid called "naphtha," vary in composition (and in sp. gr. and boiling-point) from marsh-gas, the first of the series (CH_4) up to the solid paraffins. The oils boiling below 180° (356° F.) may as solvents be conveniently divided into four portions:—(1) Those boiling below 70° (158° F.), (2) between 70° and 100° (158°–212° F.), (3) between 100° and 130° (212°–266° F.), and (4) between 130° and 160° (266°–320° F.). No. 1 may be sometimes used with advantage to replace ether and benzol economically, in varnishes belonging to Class B of Div. IV. intended to dry instantly; No. 2 may replace in Classes B, C, and D, of Div. IV., alcohol in some cases, and benzol and toluol in others; No. 3 evaporates much more quickly than turps, though not so quickly as alcohol, and may therefore be used where an essence-varnish is required to dry rather quickly, or to increase the solvent power of alcohol; and No. 4 is in many cases in Class D of Div. IV. an important substitute for turps, when it is particularly desirable to prepare an oil- or essence-varnish absolutely free from contamination by the resins always contained in turps, or which are sure to be formed in it, after it (or any varnish containing it) has been kept a few weeks.

The petroleum-oils, though rather inferior to turps in solvent power for some resins, have over it an immense advantage, in their very great stability, and resistance to the action of oxygen. They keep good for years, even in the light, without ever "fattening," and may be distilled over and over again to dryness without leaving any appreciable residue in the retort.

Shale-oils (pp. 1433, 1510).—These differ from petroleum, *inter alia*, in containing amongst their lighter oils bodies belonging to the ethylene series, whose general formula is $C_n H_{2n}$. In general characters and solvent powers, they would seem to be almost identical with petroleum.

Rosin-spirit (p. 1681) is the lighter portion of the oils ("rosin-oil") produced by the destructive distillation of common rosin at nearly a red heat. Rosin-spirit begins to boil at about 110° (230° F.), but rapidly rises to 130° (266° F.), between which point and 240° (464° F.), the greater part distils over. It has no fixed boiling-point, being a mixture of hydrocarbons even more complex than coal-naphtha or petroleum. Its odour, which in the crude product is like wood-tar, but far stronger, becomes much milder and less disagreeable after refining. It is an excellent solvent, much resembling turps, than which, after refining, it is much less oxidizable.

It was known and in common use in Italy in the 17th and probably the 16th century, under the name of *aqua di rasa* or *di raggia*, and was used for thinning varnishes.

Coal-naphtha (pp. 644–5) consists of hydrocarbons, whose general type-formula is $C_n H_{2n-6}$. The lowest term of the series, C_6H_6 (benzol), boiling when pure at about 82° (149° F.), is of very important use as a solvent for various purposes, and of more limited use in certain varnishes required to dry instantly.

The next 3 members—toluol (p. 648), xylol (p. 648), and cumol, which last boils at 166° (363° F.), are very useful solvents for some of the varnishes of Div. IV., which are required to dry hard in less time than those made with turps.

Alcohols (pp. 192–214).—Vinic or ethyl alcohol (C_2H_6O), in the form of "methylated spirit," is now the chief menstruum used for all spirit-varnishes (Div. IV., Class B) and mixed-vehicle varnishes (Div. IV., Class C). The pure ("clean") spirit, in spite of the very heavy duty paid upon it, is sometimes used in special cases, where a varnish is required to leave no smell whatever behind, as the methylated spirit always leaves a faint smell, which lasts for weeks and is very perceptible where the varnished surface is extensive, or enclosed. The methylated spirit of commerce is very pure, and generally strong enough for the commoner spirit-varnishes containing only lac, sandarach, and the pine-resins; but for those containing the copals, kauri, &c., it should be rendered as nearly absolute as possible. The best method of doing this is to shake it up with about one-tenth of its weight of salt of tartar (carbonate of potash) which has been dried at a very low red heat, then letting it lie in contact with the salt for a few days. If the salt of tartar does not remain quite dry and powdery in the spirit, the process must be repeated with fresh salt of tartar, until it ceases to absorb any more water. The spirit may then be used as it is, or distilled to remove any small impurity it may have taken up from the carbonate of potash.

No spirit should ever be used in Class C, Div. IV., which has not been thus dried. Bottles or tins containing "dried" alcohol should be kept very tightly closed, or the spirit will rapidly weaken by absorbing water from the atmosphere; and the same may be said of all spirit-, or mixed-vehicle-varnishes.

Methyl-alcohol, pyroxylic spirit, or wood-spirit (CH_4O), exists in large quantity in rectified "wood-spirit" in mixture with various other bodies, such as aldehyde, acetate of methyl, &c., and especially acetone (p. 39), a body which rather assists than otherwise the solvent power of the methyl-alcohol. Its boiling-point is lower, about 66° (150° F.), instead of 78°·4 (173° F.) and its solvent capabilities are quite equal if not superior to those of common alcohol, especially when it contains acetone (as is usually the case in the commercial article), by which also its volatility is somewhat increased. Its use is now almost confined to mixing with ordinary alcohol to make it unfit for drinking.

Propyl-alcohol (C_3H_8O) is at present too dear for use in varnishes, otherwise it would have certain advantages over common alcohol, in its greater solvent power, its higher boiling-point, 96° (205° F.) and consequent slower drying enabling it to be more easily laid on with the brush. It is also less liable to "chill" in a damp atmosphere whilst being laid on. Ether, carbon bisulphide (p. 601), acetone (p. 39), chloroform, and acetic ether (p. 39), have limited use as varnish-solvents for a few exceptional purposes, especially when the varnish has to be "floated" on to the work, as in most photographic varnishes. They have very great solvent powers over resins, but the great volatility and inflammability of the first two render their use and storage very dangerous.

Besides the before-mentioned simple solvents, a considerable number of mixed or compound solvents prepared from two or more of them (one being common alcohol), are used in the preparation of varnishes with resins which are not completely soluble in any simple solvent.

Tougheners.—These should, if possible, be of the same nature as the solid constituents of the varnishes they are intended to render more flexible, so that, on the evaporation of the solvent, they may make a homogeneous mixture with the solid residue, without any tendency to separate, which would render the varnish cloudy or opaque when dry. For water-varnishes, may be used clarified honey or other uncrystallizable sugar, "over-boiled" glue (which will not gelatinize on cooling), and especially glycerine, which, being by far the most deliquescent, should be very sparingly used, or the glazes toughened with it will certainly get sticky in damp weather. In spirit-varnishes, a great many substances are used in the trade, which though very effective for a short time after the varnish is applied, are certain to lose their flexibility after a time,—such are the turpentines, and other oleo-resins, of which the most generally used is Venice turpentine, the slowest drier of them all, but still leaving the varnish brittle after a year or so, or even in a few months in a warm climate. Far superior to Venice turpentine, but rather dearer, is copaiba balsam (p. 1639), which, by reason of the large percentage (50–60), and high boiling-point, about 250° (482° F.), of its volatile oil, retains its characters for a much longer period. The best of all substances, however, for toughening spirit-varnishes is castor-oil (p. 1380), which, being colourless, never drying, and being very soluble in alcohol, would be universally used, were it not for a tendency which it is supposed by the trade (erroneously we think) to have, of separating from the dried varnish and rising to the surface as a greasy film. Linseed- and poppy-oils (pp. 1393, 1409), are also sometimes used in spirit-varnishes, and those made with mixed solvents, in which these oils are more soluble. Manilla elemi (p. 1649) is also used, but soon loses its virtues after the drying of the varnish. Its resin, however, is very hard and tough, and has, like benzoin, the property of giving great lustre to varnish.

Essential-oil-varnishes (Class A, Div. IV.) are often brittle, and require toughening. This is usually done by the addition of a small quantity of a drying oil, which, if it exceed 20 per cent. of the resin dissolved, should be previously boiled with driers. Camphor (pp. 571–8) is also used, for though a dry solid, it has the property of making varnishes flexible and tough. It is, however, supposed to have the fault of evaporating out of the varnish in time, leaving it porous and without lustre. It ought never to exceed 7–8 per cent. of the resin.

Driers.—These are substances added to, or boiled with, the drying oils, to increase their power of absorbing the oxygen of the air, and therefore make them dry much more quickly. The only ones whose reputation has survived to the present day, are the oxides and other compounds of lead and manganese.

The principal function exercised by a "drier" is that of acting as a "carrier" of the atmospheric oxygen to the molecules of oil in its immediate neighbourhood, and this action should be, so to speak, regenerative and continuous; each molecule of the drier, after giving up some of the oxygen it contains, and thus becoming reduced to a lower degree of oxygenation, should have the power of immediately retaking the lost oxygen on exposure to the air, and re-forming the higher oxide, ready to give up a fresh quantity of oxygen to the air, and so *ad infinitum.* Manganese oxide possesses this power in a very high degree, the hydrated monoxide, which, at the moment of its precipitation, is perfectly white, changes colour in a few minutes on exposure to the air, rapidly becoming brown. It is in this state that it acts most powerfully as a drier, and, when used in quantities of less than 1 per cent., makes a very pale drying oil. Lead oxide, in quantities exceeding 5 parts in 1000, gives a very dark colour to oils when heated with them to a high temperature, as in the common "boiled oil."

MANUFACTURE.—The composition of the different kinds of varnish may now be considered. Their classification is as follows:—

Div. I.—Natural varnishes, of the Chinese, Japanese, and Indian types, containing no fixed fatty oils nor any volatile ingredients, but drying by oxidation at ordinary temperatures, and without any preparation by heat, driers, or otherwise (see p. 1692).

Div. II.—Fatty drying oils, which harden and resinify by oxidation in the air:—
- Class A.—Fat oils drying at ordinary temperatures.
  - Section α, in their natural state.
  - „ β, which have had their natural affinity for oxygen increased by chemical or other means, but without heat.
  - „ γ, boiled oils, which have been rendered more drying by heating, either with or without chemicals.
- Class B.—Drying oils, dried in a heated atmosphere (stoved), japans and enamels, oiled silk, &c.
  - Section α, raw oils, alone or coloured only with pigments.
  - „ β, boiled oils, alone or with pigments.
  - „ γ, oils combined with resins, amber, and asphaltum, and oil-varnishes of Div. III.
- Class C.—Fat oils hardened by sulphuration at high temperatures ("vulcanized oils").

Div. III.—Oil-varnishes proper.—Varnishes containing as fixed residue a drying fat oil combined with resin, either with or without a volatile solvent or diluent, and in which the quantity of oil is greater than—or at least equal to—that of the resin.
- Class A.—Oil-varnishes of the ancient type, containing no volatile diluent.
- Class B.—Oil-varnishes of the modern type, thinned with a volatile solvent, but not drying hard on the evaporation of this solvent, until the drying oil in the fixed residue has become oxidized in the air.
  - Section α, in which the oil and the resin have been boiled together at a high temperature.
  - „ β, in which the mixture of oil and resin has been effected by solution or melting together at a low temperature.
- Class C.—Black varnishes, and black japan drying at ordinary temperatures.

Div. IV.—Varnishes consisting chiefly of a resin, gum, or other solid substance, dissolved in a volatile liquid, and drying quite hard on the evaporation of the solvent.
- Class A.—Dissolved in hydrocarbons, alcohols, &c., boiling above 100° (212° F.)—"essence," "essential-oil," or "oleo-resinous" varnishes.
  - Section α, toughened with a drying oil, in less quantity than the contained resin.
  - „ β, containing no fat oil.
- Class B.—Dissolved in hydrocarbons, alcohols, ethers, &c., boiling below 100° (212° F.).
  - Section α, spirit-varnishes made with methyl-, ethyl-, or propyl-alcohols.
  - „ β, varnishes made with acetone, ethers, chloroform, &c.
  - „ γ, varnishes having as solvent a hydrocarbon such as benzol, petroleum, &c.
- Class C.—Varnishes in which the solvent is a mixture of alcohols, ethers, &c., with various hydrocarbons ("mixed-solvent" varnishes).
- Class D.—Water-varnishes.

Div. V.—Varnishes applied by heat or friction.
- Class A.—Etching-ground.
- Class B.—Heel-balls, furniture-creams, &c.

DIV. I.—Natural Varnishes.

These and the trees producing them have already been described at p. 1692. Of these, and of the methods of applying them employed amongst the natives of the countries (E. Asia) producing them, but little is known, beyond that, instead of exposing the varnished goods to warm and dry air, which is invariably required with the artificial varnishes and the drying oils, they are kept for several weeks in cool dark cellars, the atmosphere of which is made damp, by means of wet cloths hung on lines, if necessary, as though to retard the drying as much as possible.

DIV. II.—Fat oils drying by oxidation.

Class A.—*Drying at ordinary temperatures.*—Section α.—In very hot and dry climates, the drying oils will, sometimes in the course of a few days, form a regular varnish when applied in very thin layers; such varnish, however, seems never to dry thoroughly hard, but retains a leathery consistence more resembling indiarubber. This, in some cases, is a positive advantage, especially where the work to be protected is liable to much alternate contraction and expansion, e.g. boats, out-of-door woodwork, tarpaulins, &c. This result is obtained in colder climates by the use of the oils of the two following sections.

Section β.—Raw drying oils have, from a very early period, possibly before the 10th century, had their drying powers increased by a great variety of methods, all of which resolve themselves in principle into two only, viz.: 1st, exposure in extended surfaces to the air and sunlight; and 2nd, combination with lead in some form or other.

Sometimes both these principles are combined, e.g. exposing to air and sunlight in shallow leaden vessels, or on the roof of a house in white glass bottles containing plates or shavings of lead, &c. The oils thus produced, though often nearly colourless and tolerably good driers, have no commercial application, and are almost entirely disused, except perhaps by a few painters of pictures. Recipes for their preparation will be found in abundance in old works on painting materials.

Section γ.—" Boiled Oils." The various processes formerly in use for preparing "boiled oil," and which will be found scattered through the older works on painting and varnish-making, are nearly all dependent on the singular power of salts of lead in causing the rapid oxidation, on exposure to the air, of the drying oils in which they are dissolved. Manganese oxide in the form of umber (a manganese ochre) was also sometimes used.

The action of lead is due partly to a similar power of easy transition between two different degrees of oxidation, aided perhaps by its greater solubility in the oil, but it evidently also exerts some other influence not at all understood, and seems, even when present only in very small quantities, to accelerate immensely the "carrying" power of oxide of manganese when used in conjunction with it. Lead oxide (or lead salts), used alone, is quite sufficient to raise linseed-oil to the highest possible degree of drying power, but it unfortunately at the same time gives it a very deep reddish-brown colour.

In boiling oil according to the old method, the action of the air is confined to the surface of the oil in the copper, and no provision is made for the renewal of that surface (so as to bring fresh portions of the oil into contact with oxygen) beyond an occasional stirring up of the litharge settled at the bottom, and the circulation kept up by the heating of the oil. In the modern process, air is forced, in as rapid a stream and as finely divided a state as possible, through the mixture of hot oil and driers, and brought into the most intimate contact with it by powerful mechanical agitation; the time of boiling is thus reduced to one-third, and the oil is less coloured. By the introduction of mixed driers of lead and manganese,—the reduction of the quantity of lead oxide from 10 per cent. to less than 1 per cent.,—and the lowering of the temperature from the melting-point of lead to the boiling-point of water, a "boiled oil" can now be produced equal in drying power to the old-fashioned lead-oil, and scarcely deeper in colour than the original raw oil.

Apparatus required.—For boiling oil according to the old method, all that is required on the large scale, is a tight-made copper boiler with a tight-fitting lid, and set in brick-work, with a furnace, &c., connected with a tall and wide chimney. This copper differs little, except in size, from an ordinary wash-house copper, but should be provided with a hood connected with the chimney, to carry off the suffocating vapours given off by the oxidizing oil. Its construction and use, with an excellent description of the old method of boiling oil, will be found in a paper on varnish-making, published in the 'Transactions' of the Society of Arts, vol. xlix., by Wilson Neil, to which the reader is referred.

For boiling oil according to the modern methods, a very different, and far more complicated, as well as much larger, apparatus is required, consisting of a copper or enamelled iron boiler of 100–200 gal. capacity, furnished with a revolving fan stirrer (with interlocked blades revolving in opposite directions), and capable of being raised to a temperature of 120° (248° F.) by a steam-jacket or a coil of pipe. It must also be connected with a powerful force-pump, by which a stream of air is forced through a ring of pipe at the bottom of the boiler below the fans, pierced with very small holes. Thus minutely divided by the holes in the pipe and the action of the stirrer, the air is most intimately mixed up with the oil, which is frothed up to nearly twice its proper bulk. The apparatus is also furnished with a dome, carrying a large exhaust-pipe leading to a tall chimney-shaft, or, better still, to the ash-pit of any furnace with a good draught.

Into this vessel, the oil is introduced, in quantity equal to half its capacity, and when it has attained a heat of 100°–120° (212°–248° F.), the stirrer is put into action, the driers (ground in oil to the utmost possible fineness) are poured in little by little, and when thoroughly mixed with the oil, the air is turned on, the heat and the stream of air being kept up for 3 or 4 hours, or until the oil, by the appearance of samples taken from time to time, is found to be sufficiently "boiled."

For lead-dried oil, and where colour is no objection, the apparatus described under the head "Linoleum" (p. 1003) may be used.

Recipes.—Almost any of the salts and oxides of lead and manganese may perhaps be used as driers, but those now almost universal, are the acetate, the protoxide (litharge, massicot, &c.), red-lead or minium (a combination of protoxide and binoxide of lead), and the carbonate or "white-lead"; sulphate, acetate, borate, benzoate, and other salts of manganese, as also its protoxide (freshly precipitated) and peroxide, or any of the intermediate oxides, and their corresponding hydrates. The quantity added may vary from 1 to 20 parts of the two metallic salts to 1000 of clarified oil; or if a lead-dried oil is wanted, from 1 to 10 per cent. of any of the above-mentioned compounds of lead, according to whether the oil is required to be merely a drying oil, or to assist the drying of other oils to which it is added.

The following examples will serve as illustrations (all the oil used is supposed to have been clarified, as described at p. 2024):—

Order 1.—*Lead Oils.*

Old process.

a. Linseed- or nut-oil	1 gal.
Litharge	1 lb.

Oil raised quickly to about 280° (536° F.), the drier added little by little, and the heat raised to 300° (572° F.) and kept so for 6–12 hours, according to drying power required.

b. Linseed- or nut-oil	1 gal.
Litharge	½ lb.
Sugar of lead	½ „

Treated as above.

The above, after having sufficiently boiled, are to be closely covered, allowed to slowly cool undisturbed for about 12 hours, most carefully poured or ladled off the dregs, and then laid by to settle for a few months, or indeed as long as conveniently possible.

Modern process.

The process described under the head Linoleum may be employed with advantage—doubling the amount of driers, and stopping the air-blowing before the oil begins to thicken; and if a pale oil is desired, lowering the temperature to 150° (302° F.) and using a copper, or enamelled-iron boiler.

Order 2.—*Manganese Oils.*

Old process.

a. Linseed-oil	1 gal.
Potassium permanganate ..	100 gr.

The oil is heated to about 300° (572° F.), and the permanganate of potash, previously ground very fine in some of the oil, is added little by little. The oil will froth up at each addition, and the drier will then dissolve quietly. The heat should be kept up for 2 or 3 hours with frequent agitation.

The boiler should be of enamelled iron.

b. Linseed-oil	1 gal.
Pure hydrated protoxide of manganese	½ oz.

Grind the freshly-precipitated protoxide of manganese with some of the oil, add the mixture to the remaining oil at 300° (572° F.), and keep it at that temperature till a sample begins to thicken when cold; it may then be restored to proper thinness by the addition of a little raw oil, and set by to deposit sediment.

Modern process.

The above formulæ may be used for oils treated in the modern way, as already described, at a low temperature, and with powerful agitation, with a stream of air blowing through the mass.

Order 3.—*Manganese and Lead Oils.*

Old process.

a. Linseed-oil	1 gal.
Umber	5 oz.
Gold litharge	5 „
Red-lead	5 „

Simmer together for 6 hours.

b. Linseed-oil	10 gal.
Permanganate of potash	4 oz.
Acetate of lead	4 „

The permanganate and the sugar of lead are each dissolved separately in 4 pints of water, then the two solutions are mixed together and added to the oil, cold, and with strong stirring. The oil is then heated gently until the water is boiled off, and then to about 300° (572° F.) until it begins to thicken a little (tried by cooling a drop on a piece of glass).

c. Linseed-oil	1 gal.
Borate of manganese	1 oz.
Acetate of lead	1 „

d. Linseed-oil	1 gal.
Manganese protoxide-hydrate	1 oz.
Red-lead or litharge	1 „

New process.

The same driers as above, in the formulæ *b*, *c*, and *d*, but treated, at a temperature of between 100° and 120° (212°–248° F.), with a strong stream of air blown through the oil, and powerful mechanical agitation, for about 4 hours, or until the oil shows signs of thickening when tried on glass. If wanted for "drier" to paints or other oils, the action may be carried on until the oil is nearly solid when cold, the doses of driers being also much increased. In this case, the thickened oil should be thinned with an equal bulk of turps. Processes *b* and *d* give very quick-drying oil.

Many other substances have been tried as driers for boiled oils, such as barium peroxide, mercuric oxide (red precipitate), chromic acid, lead chromate, and others, but without any satisfactory results.

Class B.—Stoved Japans and Enamels.—In this class, the oxidation of the oil is effected at a high temperature, varying from 50° (122° F.) to 150° (302° F.), and even higher where the goods to be japanned will resist the heat. The temperature must also be regulated according to the paleness or delicacy of the colours, a high temperature giving a brown colour to the oil or varnish used, for white, bright blue, pink, &c., having to be kept as low as 65° (149° F.), whereas for dark or dull colours, and brown and black, the heat may be as high as 150° (302° F.) for soldered tinware, or even much higher for iron or other goods that will stand it. The time of stoving will be, *cœteris paribus*, in inverse ratio to the temperature; thus delicate colours at 70° will take 24–48 hours' stoving, whilst coarser or darker colours at 100° or 150° will be quite hard in 6–12 hours.

The time will, moreover, vary according to the degree of flexibility and elasticity it is considered desirable that the japan should retain. Where great elasticity is required, as in japanned leather, and oiled silk, and in the tinplate intended to be stamped or blocked *after* being japanned (where the utmost degree of toughness is required), the temperature should be as low as 50°–100° (120°–212° F.), and the time, 6–24 hours. Another important factor, regulating both heat and time, is the more or less drying nature of the oil or varnish used.

When carefully carried out, and not too much forced in the stoving, this mode of varnishing can be made to yield results little, if at all, inferior to the finest natural varnishes of India, China, and Japan. The only drawback is the heat required, to which, objects of wood and some other materials cannot be exposed without warping or splitting.

Instruments and Plant.—The only essential apparatus required is a heated closet or chamber of sheet iron or other material, of dimensions varying with the business needs of the establishment, from one to many cub. yd. capacity. The principal point to be aimed at in its construction is to secure a uniform degree of heat in the whole of the chamber, together with a steady but slow draught of atmospheric air through its interior. Any mode of heating may be adopted which will give a steady unvarying heat for any length of time, and of any required degree, and at the same time be under perfect control. This is effected by the appropriate circulation of the furnace flues round (in heating by gas, they may be inside) the chamber, taking care to protect the lower portion, where the impinging heat is greatest, by a proper thickness of brick or tile.

The interior of the closet may be furnished with ledges at the sides, at various heights, to receive shelves, iron bars, wire netting, &c., to suit the size and shape of the japanned goods. The objects should be arranged as regularly as possible, leaving sufficient space between them on all sides for the free circulation of the hot air, and also to prevent the vapours given off by the heated varnish from softening the coating of japan and causing it to "run," wherever two surfaces are too near together. Very small surfaces may be nearer together than large ones. The same accident may also be caused by insufficient draught of air at the commencement of the stoving.

It is desirable that, in applying the japan, the strokes of the brush should have such a direction as will ensure their being horizontal when the object is standing in the stove, otherwise the varnish will run into vertical streaks and rollers, utterly disfiguring the work. The varnish too, unless thickened with pigments, should be itself of sufficient consistence to hold its place on the japanned surface at the heat of the oven, and when oil alone is used, it should be boiled until nearly solid, and thinned with turps to enable it to be laid on with the brush. Otherwise the coats must be so very thin as to necessitate inconvenient multiplication.

Materials.—Any drying oil or oil-varnish may be used for stoved japan, according to the required quality and nature of the result, but if oil-varnish be used, it should in all cases be highly charged with the oil; thus an oil-varnish of the Continental type (see Div. III.) will not give so tough and resisting a japan as one of the English type, in which the oil forms at least ¾ of the fixed residue.

For pale transparent japans (stoved lacquers), may be used a pale and very thick boiled oil, prepared according to the modern process, or the best and palest carriage- or body-varnish diluted with one-third or one-quarter of very old raw linseed-oil. If required to be coloured other than its natural golden colour, any transparent colour, such as lake, Prussian blue, French ultramarine, verdigris, and some of the aniline colours, previously ground in pale boiled or raw oil, may be added. Heat, about 80° (176° F.). Time, 24–48 hours, or even more.

For white, ordinary white-lead, or flake-white, or zinc-white ground in the palest boiled oil (modern process) for first coats, and the same, with the addition of the palest body-copal-varnish for the finishing coat if required glossy. Heat, below 65° (149° F.), if very pure white is required. Time, 24–48 hours.

For pale delicate colours (opaque), the same white, to which are added any pure-tinted pigments that can stand the heat, either transparent, such as those mentioned above, or opaque, such as vermilion, Naples yellow, emerald green, cobalt blue, &c. Time and heat as for white.

For dark and coarse colours, any boiled oil may be used, if sufficiently thickened with pigments or by boiling, to hold its place during the stoving, either with or without the addition of a good dark-coloured real copal- or amber-varnish.

Many of the common (so-called) "copal" varnishes made with white dammar, inferior kauri, or Manilla copal, make inferior japans. Heat, 150° (302° F.) for about 12 hours.

For pale transparent browns, nothing is finer than good amber-, or dark real copal-varnish, added to half its bulk of boiled oil, and stoved at 150° (302° F.), if the wares will stand the heat. Soft solder becomes weakened at 160° (320° F.), therefore soldered tinware ought not to be stoved at a higher heat than 150° (302° F.).

Darker browns may be obtained by addition of umber (finely ground in linseed-oil), asphaltum, Brunswick black, or "black japan" varnish. Blacks, by the addition of calcined lamp-black, or (for the best quality) finely ground ivory-black to the above browns. Heat, 150°–250° (302°–482° F.). Time, 6–24 hours.

In all cases where varnish diluted with turps is used, the japan must be quite dry before being stoved, or it will infallibly run into streaks when heated, and the greatest care must be taken to keep away dust until they are quite dry.

In japanning leather, the flesh side of the skin is scraped and shaved smooth, and rubbed to as even a surface as possible, and prepared with:—Raw linseed-oil, 1 gal.; litharge, 1 lb.; burnt umber, 1 lb.; boiled together according to old process at high temperature until the oil is much thickened when cold, and then allowed to settle and poured from the dregs. This oil, with the addition of a little burnt umber and ochre, finely ground, is well worked and rubbed into the flesh side of the leather, and the excess scraped off; it is either allowed to dry in the air, when the weather is hot and dry, or is stoved at a very gentle heat of about 40° (104° F.). Some 2 or 3 coats are thus applied, then 2 or 3 of the same oil with the addition of some finely ground ivory-black, and finally 1 or 2 of the oil alone. When all is thoroughly dry, the leather is stretched very tight, and the varnished surface is rubbed down very smooth with fine washed pumice powder, and then varnished with any of the above black japans, or asphaltum and copal oil-varnishes, and stoved at 40° (104° F.). The very greatest care must be taken to exclude dust during the varnishing, the smallest quantity ruining the varnished surface. (See also p. 1236).

Oiled Silk.—This may be prepared with 2 or 3 very thin successive coats of any boiled oil, stoved at a temperature of 40°–100° (104°–212° F.), the silk being stretched over light frames of deal laths.

Div. III.—Oil-varnishes.

The successful preparation of these varnishes is the most difficult branch of the varnish-maker's art, and requires the greatest knowledge, experience, and care, together with a skill which cannot be taught by precept, but is to be acquired only by long practice and observation. The process may be divided into two principal stages: 1st, the preparation of the resin, rendering it soluble in the oil; 2nd, its incorporation with the oil in such manner as to form a compound which shall be perfectly soluble in essential oil of turpentine, and, on the evaporation of the latter, shall dry hard within a reasonable time, and before dust has, under ordinary circumstances, been able to attach itself to the varnished surface to any serious extent.

The resins best fitted for the composition of oil-varnishes are, as already pointed out at p. 2024, insoluble in any known menstrua, and are incapable of true fusion. The first effect of the application of heat to all of them, except sandarach and the very softest copals, is to make them soft and elastic like hot indiarubber. On increasing the heat, the resin, at about 300° (572° F.), begins to froth and swell up, giving off water, acids, and empyreumatic substances, chiefly hydrocarbons of various degrees of volatility, this action increasing with the heat until it has reached its so-called "fusing-temperature," and has become converted into a mixture of new and entirely different hydrocarbons, some solid, some liquid, and some gaseous at ordinary temperatures. This fusing-point is extremely high, being above the melting-point of lead, and only just below an incipient red-heat. Of the liquid products of the decomposition, some have a boiling-point but little if at all below the "fusion point" of the resin, have a very high vapour-density, and play a very important part in its successful fusion for varnish-making.

In the above enumeration of the effects of heat, the resin is supposed to have been fused in the way usual in varnish-making, i. e. confining these vapours as much as possible in a very deep vessel. The resin in such circumstances will become reduced to about $\frac{5}{6}$ of its weight, to a transparent, thin oily liquid, which may be no more coloured than pale amber, or linseed-oil, if a very pure and pale resin has been operated on. On the surface of the liquid resin, will be seen floating a stratum of heavy transparent vapour, which may be poured out like water by carefully inclining the vessel, and will condense against any cool object into a thick oily liquid of pungent though aromatic odour. If the resin, immediately on its complete fusion, be poured out upon a cool surface, it will solidify into a brittle rosin-like substance totally different in character and composition from the original resin. It is now soluble in hot linseed-oil, in turps and other essential oils, chloroform, petroleum, rosin-oil, ether, benzol, and many other hydrocarbons.

If, instead of being heated in a deep or closed vessel, the fusion be attempted in a shallow vessel such as a ladle or evaporating dish, the result will be very different. On the application of the heat, the resin will first soften and tumify as in the previous experiment, but after this, instead of fusing quietly, it will gradually become browner and harder, until it is entirely converted into a porous mass of charcoal and the aforesaid heavy vapours, which in this case are carried off with the currents of air playing round the heated ladle.

If, instead of pouring out the resin melted as in the first experiment, it be allowed to cool undisturbed in the vessel in which it has been fused, together with all the above-mentioned heavy vapours, these latter on condensing will wet the upper portion of the solidified resin, and dissolve it into a thick syrupy liquid.

From a careful consideration of the above facts it may safely be concluded :—

1st. That an oxidizing atmosphere blackens and chars the fusing resin.

2nd. That the above-mentioned heavy volatile hydrocarbons, forming a continually renewed bath of heavy vapour floating over the surface of fusing resin, effectually keep off the atmospheric air when the fusion takes place in a deep vessel.

3rd. That the least volatile of these hydrocarbons, which are liquid at the heat of the half-fused resin, materially assist in the liquefaction of the yet unfused portions, at the same time protecting the fused portions from becoming coloured by the further action of the heat.

Bearing in mind the above facts and conclusions, the reader will easily see the reasons for all the following rules and directions.

Preparation of Resin.

1. Remove outside coating of crust with a sharp knife of hard steel, if not already done by the merchant, by scraping or washing in alkaline lyes.

2. Carefully pick over the resin, setting aside the purest and most transparent and colourless pieces for the best quality of varnish, and dividing the remainder into 2 or 3 qualities according to paleness, transparency, and purity.

3. Look over each separate lot, and with the knife or with cutting nippers, remove all those portions containing earth, bits of stick, leaves, insects, and any other impurities.

4. Cut up the pieces of resin by halving each separately until they are reduced to the utmost possible evenness of size, looking like granite road-ballast in miniature, and in fragments of the size of peas or beans, or small hazel-nuts, the exact size being of less importance than evenness of bulk. Therefore it is better to sift them, through different sized mesh sieves, into 2 or 3 categories, so as to ensure sameness of size for each melting.

Fusion of Resin.

5. Place the required quantity of resin thus prepared in the melting-pot or "gum-pot" (on the small scale, in experiments on only a few oz., this may be a round-bottomed glass flask), and, if the heat is thoroughly under control, as where gas is the fuel, heat the resin very gently for some time until it has got thoroughly warmed through at a temperature of about 150° (302° F.), and then raise it as quickly as possible to the fusing-point, keeping the resin stirred and divided in all directions as rapidly as can be done with a strong metal spatula or stirrer (or, on the small scale, by shaking the flask with a circular motion), and taking care that the resin, which now froths up to 5 or 6 times its natural bulk, shall not boil over out of the vessel. This vessel should have a capacity of at least 10 times the bulk of the resin to be melted at one operation.

If the fusion has been properly conducted, the stirring active, and especially if the pieces of resin were all of nearly equal size, the last lumps of unfused resin will disappear from the frothing mass in about 10 minutes from the increase of the heat. To ascertain this, it is necessary to keep taking up samples with the spatula from time to time, and towards the completion of the fusion, this should be done every few seconds. The moment the fusion is complete, which is moreover generally announced by the sudden diminution of the frothing, the "gum-pot" is at once removed from the furnace (or the gas turned off), and preparations are made for mixing in the hot oil, if the varnish is to be made according to the mode most usually practised, which is also the most ancient. If, however, the varnish is to be made according to some process in which the cooled and solidified resin is used, as in some varnishes of Div. IV., the gum-pot must be immediately emptied, pouring out the fused resin upon metal plates (silvered copper by preference) to cool in sheets $\frac{1}{4}$–$\frac{1}{2}$ in. thick.

The oxidation and browning of the resin may be still further prevented by fusing it in a closed copper vessel through which a slow current of coal-gas is passed during the fusion.

Combination with the oil.

This may be effected in either of the three methods already mentioned. 1st, by pouring the hot oil into the resin immediately on its being perfectly fused. 2nd, by allowing the fused resin to cool and solidify, and then dissolving it in the oil by heat. 3rd, by fusing the raw resin in the oil itself, in a reducing atmosphere if possible.

The first method is that generally if not always adopted in England. The oil, raised to a temperature of about 315°–320° (599°–608° F.), is kept at that heat whilst the resin is fusing, and the moment the fusion is complete, the melting-pot is removed from the furnace, the proper quantity of oil (previously ladled out into a copper pouring vessel) carried to the melting-pot, and, as soon as the frothing of the melted resin begins to subside a little, the hot oil is poured in a thin stream and with steady stirring into the boiling resin. When all the oil has been poured in and well stirred into the resin, the melting-pot is replaced on the furnace, and the oil and resin are boiled together for a few minutes, or until a drop received on a strip of window-glass, remains transparent when cold, and does not become dull or semi-opaque. The varnish, however, is far from being finished at this stage, and would take too long to dry, besides not giving the lustrous and hard surface required of an oil-varnish, and would moreover be most likely curdled or coagulated on attempting to thin it with turps for ordinary use. To give it the qualities desired, it must undergo a further boiling at a lower temperature, in a vessel of larger dimensions and shallower form, exposing a greater surface to the action of the air, which action may be assisted by agitation, or a blast of air playing over the surface of the hot varnish. During this second boiling, may be added appropriate driers (where the varnish has been made with raw oil, and is required to dry quickly), as for boiled oil. Several meltings or "runs" of varnish of the same kind and quality are usually boiled together in this second boiling, which will take from 10 minutes to as many hours, according to the nature and proportion of the resin employed, and the description and drying quality of the varnish. The progress of the operation is examined from time to time, especially towards its termination, by placing a drop upon a strip of window-glass, and observing whether or not it looks clear and brilliant, with a lustre that is difficult to describe in words, but which is nearer "adamantine" than "resinous" or "oily" in mineralogical language. It will now also, if sufficiently boiled, be capable of being drawn out into long threads, and will feel sticky instead of oily, when the drop has cooled. When it thus "strings" well, to a length of 6 in.–6 yds., according to the nature of the varnish required, the boiling has proceeded far enough, and the varnish is completed to all intents and purposes, forming Class A of Div. III.

Wherever it is possible to apply it in this thick state (by heating the object to be varnished, or otherwise) it makes the most perfect and durable as well as brilliant of all the oil-varnishes, the subsequent thinning with turps required for allowing it to be used with the brush, having no effect on the varnish so thinned but to injure its finest qualities. This thinning with turps must be done at a great distance from any light or fire, best of all in the open air, for fear of explosions. The boiling-pot should be taken off the fire (or the fire perfectly extinguished),—the varnish allowed to cool to about 80° (180° F.), or so far as to lower its temperature to about 50° above the boiling-point of the diluent or solvent added, and the turps, hot but not boiling, poured in little by little in a thin stream, with very cautious stirring of the surface only of the hot varnish, and waiting for the frothing to subside after each addition before adding more turps.

If the varnish were stirred down to the bottom when adding the first portions of turps, there would be great danger of the boiling up becoming so violent as to almost completely empty the boiling-pot of its contents. When all the turps has been thus added, or when the varnish, on cooling a small quantity in a shallow vessel, is found to be sufficiently thinned, it is strained through a fine wire-gauze sieve, set by to clear, and stored for keeping. Varnishes thus diluted form Class B of Div. III.

The above is a rough sketch, omitting details, of the most generally used, as well as the oldest method of making a true oil varnish; by this process, any quantity of varnish may be successfully made, from a few grains in test-tubes and small capsules, to many hundredweights.

In the second method, which was brought strongly into notice (though not invented) by Tingry, in the beginning of this century, the resin is fused with all the precautions above described, allowed to solidify in thick sheets, and when cold is coarsely powdered and introduced with the *cold* oil in proper proportion, into the boiling-pot, but bearing in mind that 3 parts of the fused resin are generally about equivalent to 4 parts of raw. The resin and oil are then boiled together, and the varnish finished just as in the method above described. The varnishes thus produced differ in nothing from those made by the old process.

In the third process, the resin, which in this case may be in powder or otherwise, is introduced *raw* into the cold oil, and the whole heated with the same precautions as for fusing the resin alone.

The following will serve for examples:—

Proportions.

a. Palest amber picture varnish.

Palest transparent yellow amber	1
Palest old linseed-oil	1½
Fresh distilled turps	3

Boiled to string well at the lowest possible temperature.

b. Body copal-varnish.

Palest Zanzibar animi	1
Linseed-oil	3

Made into a varnish and added to—

Sierra Leone copal	1
Linseed-oil	3

Made into a varnish.

These are boiled together until they string well, and diluted with turps 12

c. Neil's picture varnish.

Very best African copal	1
Linseed-oil	2½
Turps	3

d. Gold-size.

Amber or copal	1
Linseed-oil	2

Boiled until it strings well, and then added to 6 parts of boiling and very drying boiled oil, and the whole boiled together until it strings very well, then diluted with 10 or 12 parts of old turps.

Class C.—Black oil-varnishes and black japans drying at ordinary temperatures.—These are merely oil-varnishes of Class B, and made in exactly the same way, but where asphaltum is used alone and without any amber or copal, they require much longer boiling.

Order 1.—Containing amber or copal.

Black Japan.

Asphaltum	6
Linseed-oil	12

Boiled together until nearly solid when cold—then add to it the following, made into a varnish—

Animi	1
Linseed-oil	2

and—

Amber	1
Linseed-oil	2

The whole then boiled together 2–3 hours, thinned with turps, and then strained.

Order 2.—Containing only asphaltum.

Brunswick black.

Asphaltum	3
Linseed-oil	4

The asphaltum is fused alone, and kept boiling for 6 hours, and in the meantime the oil is boiled with lead driers until very drying. They are then mixed and boiled until a drop allowed to cool can be rolled into a hard pill between the fingers. It is then thinned with 12–16 parts of turps, and strained.

Div. IV.—Containing a gum, or resin, dissolved in a volatile liquid, and drying hard on the evaporation of the solvent.

Class A.—Dissolved in hydrocarbons, alcohols, &c., boiling above 100° (212° F.)—"Essence," "Essential-oil," or "Oleo-resinous" varnishes.

Section *a.*—Toughened with a fat oil.

Order 1.—Resins fused and boiled with oil as for an oil-varnish, but with less oil than resin.

These varnishes are usually looked upon as oil-varnishes, but the oil being in small quantity and not the principal component of the fixed residue, and the varnish therefore drying hard on the complete evaporation of the solvent, they naturally are included in Div. IV. of the classification. They are made precisely as oil-varnishes, but require only a few minutes' boiling to get stringy, and seldom want driers. Most of the regular oil-varnishes of the formulæ published in French works on varnish-making come under this head.

a. Mixed amber-varnish.

Amber, palest	1
Copal or animi (palest)	1
Sandarach (very clean)	1
Linseed-oil	2

Fuse the resins together, add oil very hot, boil as for an oil-varnish, and thin with turps.

b. "Vernis pour equipages."

Sandarach	2
Boiled oil	1
Turps	about 3

Sandarach fused in the oil, boiled to string, and the turps added hot.

c. "Vernis blanc au copal" (Watin).

Picked copal	2
Boiled oil	1
Turps	3 or 4

Melt the copal in a glass flask, add oil very hot, boil till stringy, and add turps hot.

d. Kauri varnish.

Kauri (pale)	2
Pale boiled oil	1
Turps	2 or 3

Dissolve resin in oil, boil till stringy, add boiling hot turps, and strain boiling hot.

Order 2.—Made with previously fused resins, but dissolved, together with the toughening oil, at a low temperature in the solvent.

In this and all the following orders of varnishes, the manufacture requires no special skill or training, but can be easily carried on by any one acquainted with the roughest laboratory manipulation. Neither is any special apparatus required, beyond tins, bottles, and other storing vessels, large funnels, filters, filtering paper, stirrers, measures, and other common workshop appliances. No directions therefore need be given beyond those for choice of materials.

a. Palest fused amber	4
Pale boiled oil	1
Turps	about 6

Dissolve the oil and resin in the turps at a gentle heat—in the water-bath best, but the amber must then be powdered.

b. Animi fused	3
Very drying boiled oil	1
Turps	5

Proceed as in *a.*

Order 3.—Made with resins not requiring previous fusion for solution in turps.

Section *α*.—These differ from those of section *β* only in the substitution of boiled oil (5–25 per cent. of the resin used) for the toughener. With this difference, the proportions are similar.

Section *β*.—Containing no oil, but toughened with an oleo-resin.

Order 1.—Resin not fused.

a. Best mastic picture-varnish.

Palest picked mastic in tears	4
Oil of lavender	$\frac{1}{2}$
Camphor	$\frac{1}{16}$
Turps	8

All dissolved together in the turps at the heat of the water-bath, stirring all the time.

b. Common mastic varnish.

Mastic	1
White dammar	1
Turps	4
Camphor	$\frac{1}{16}$

Treated as in *a*, or heated in the turps until the resins melt, when they will mix easily.

c. Black dammar in fine powder	4
Copaiba balsam	1
Turps	8

Turps boiled with the resins.

d. A very cheap varnish.

Pale rosin	10
Rosin-oil	1
Petroleum, No. 3 or 4	15 to 20

Where the smell is of no importance this may be made with rosin-spirit.

Order 2.—Made with fused resin—have similar formulæ as to proportion and toughener.

Class B.—Dissolved in hydrocarbons, alcohols, ethers, &c., boiling below 100° (212° F.), "spirit-varnishes" and "ether-varnishes."

Section *α*.—Spirit-varnishes proper, made with methyl-, ethyl-, or propyl-alcohols, "French-polishes," and "spirit-lacquers."

Concerning these, little need be said beyond urging the use of the strongest spirit that can be obtained, in many cases further drying it by potassium carbonate (see p. 2026). Brittleness may be removed by tougheners, in the following proportions to the resins:—

	Per cent.
Cold-drawn castor-oil	5 to 10
Copaiba balsam	5 „ 20
Venice turpentine	10 „ 50

	Per cent.
Camphor	2 to 10
Oil of lavender	10 „ 25
Fat old turps	10 „ 50

Order 1.—Containing lac as the principal ingredient.

These are the hardest of all artificial varnishes, with the exception of the stoved oil-japans.

a. Pale lac varnish.

Bleached lac freed from wax	1
Methylated spirit	3

Powder the lac coarsely, and dissolve it in the spirit with a gentle heat, filter it warm, covering the funnel closely during filtration, and let it settle until bright.

b. Shell- or button-lac	8
Soft Manilla copal, palest possible	6
Copaiba balsam	2

Treated as *a*, and dissolved in strongest spirit 40

c. Lac	5
Sandarach	2
Elemi	1½
Venice turpentine	2
Spirit	24

d. Lac	6
Pale rosin, or American thus	3
Sandarach	2
Castor-oil	1
Spirit	30

e. Bleached lac freed from wax	10
Mastic	6
White dammar	4
Oil of lavender	8
Spirit	50

Order 2.—Containing little or no lac.

a. Palest soft Manilla copal	4
Manilla elemi	1
Spirit, dried	12

Proceed as in Order 1, *a*, but using the strongest dried spirit.

b. A pale cheap varnish.

Sandarach	2
White dammar	2
American thus	4
Soft Manilla copal	4
Elemi	4
Spirit	40

c. American thus	4
Benzoin	2
Manilla elemi	2
Sandarach	2
Spirit	25

Filter when dissolved.

d. Sandarach	4
Palest soft Manilla copal	4
Copaiba balsam	2
Castor-oil	1
Spirit	25

Proceed as in *a*.

Order 3.—Spirit varnishes applied with a rubber—"French polish."

These are merely lac-varnishes made rather thinner than the regular spirit-varnishes, and to which is sometimes added a small percentage of boiled oil, or copal oak-varnish. Their quality is good in direct proportion to the amount of lac contained in them, all attempts to substitute cheaper resins deteriorating the hardness and smoothness of the polish. Elemi, mastic, or benzoin, in small quantities are perhaps an improvement.

a. Seed-lac	1
Spirit	5

Shaken till dissolved, but not filtered.

b. Shell-lac	8
Mastic	2
Benzoin	1
Copal varnish	1
Spirit	50

Order 4.—Coloured spirit-varnishes or "spirit-lacquers."

Very dilute spirit-varnishes, coloured to suit requirements and, like the last order, good in direct proportion to the amount of lac in them. They should be made with the strongest dried spirit, and where possible the work should be warmed before the application of the lacquers, and the temperature of the air between 20° and 25° (68°–77° F.), or there is risk of the lacquer "chilling," especially in damp weather. The air must also be free from dust, every particle of which will make a deeper-coloured spot. The gold-coloured lacquers for brass-work are the most abundantly used in the arts, gamboge modified with dragon's-blood being the usual and best colouring. Fancy colours may be given in every variety with any of the aniline colouring matters soluble in alcohol. Of the immense number of different formulæ for lacquers, the following will suffice as examples, all of them to be well filtered and allowed to settle till bright.

a. Gold lacquer.

Seed-lac	4
Gamboge	1 to 2
Dragon's-blood	½
Dried spirit	36

b. Deep gold.

Seed-lac	10
Turmeric	4
Gamboge	4
Dragon's-blood	1
Dried spirit	80

c. Pale brass.

Bleached lac	12
Aloes	2
Gamboge	1
Dried spirit	100

d. Bronze.

Lac	4
Sandarach	2
Gum acaroides	2
Gamboge	2
Aloes	2
Dried spirit	80

Section β.—Made with ethers, chloroform, acetone,—"ether-" or "etherial-" varnishes.

Being used only in small quantities, and for very special purposes, these varnishes may be dismissed with a few general considerations. Owing to the great volatility of the solvent, they are difficult to use with a brush, and are much better applied by "floating" or dipping. The solvents should always be well dried with salt of tartar, as described under "alcohols" (p. 2026), and, in the case of ether and chloroform, should first be well washed 2 or 3 times with an equal bulk of water, to remove excess of alcohol.

Section γ.—Made with a hydrocarbon solvent boiling below 100° (212° F.).

Of these solvents, the most powerful are the benzol and toluol series (p. 2026), which dissolve all resins soluble in chloroform (except benzoin), and many others.

Petroleum Nos. 1 and 2 yields very few varnishes, owing to its restricted solvent powers, being almost confined to mastic, white dammar, and coniferous resins; otherwise, from its great stability and cheapness, and its easy purification, it would be the most eligible of all hydrocarbon solvents.

Class C.—Mixed solvent varnishes.—In this class, the menstruum consists of alcohol, ether, chloroform, acetone, &c., to which is added ¼–½ their bulk of a hydrocarbon, such as turps, benzol, petroleum, &c. These solvents have their power so much increased that all varnish-resins are soluble in them, except amber and the hard copals. Where an alcohol is used as one of the components, the added hydrocarbon should be divided into two parts, only one of which is mixed with the alcohol before the solution of the resin, the second part being added to the varnish after it is completed and filtered; the risk of precipitation of the resin by the unequal evaporation of the mixed menstruum on keeping, is thus greatly diminished. All alcohols, ethers, and chloroform used in these varnishes should be well dried. As examples, the following are given :—

a. Kauri (palest)		2
Mastic		1
Chloroform	1	9
Spirit	3	

b. Soft pale copals		3
White dammar		1
Bleached lac		1
Toluol	1	12
Spirit	3	

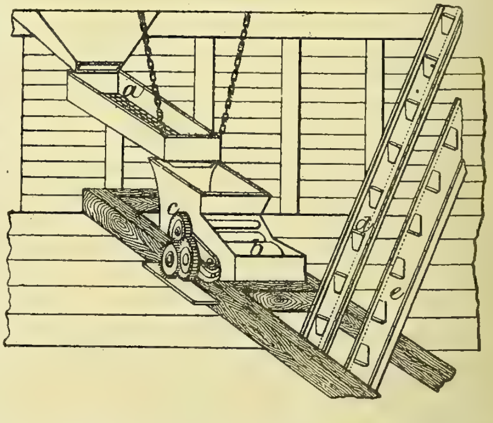
Class D.—Water-varnishes.—Albumen and gelatine being the chief ingredients in these glazes, they should, if not used immediately, be mixed with some organic antiseptic, such as carbolic acid, thymol, or salicylic acid. Borax and especially boracic acid are also excellent (inorganic) preservatives, but render the glaze rather opaque when dry, and diminish the gloss. These glazes may be coloured with any of the soluble aniline or other colours.

The author acknowledges with pleasure the great help received from E. M. Holmes, F.L.S., whose immense store of information concerning resins, &c., has always been most kindly and cheerfully placed at disposal. To Robert Finch (japanner), are also due many valuable details respecting stoved japans. E. F.

VINEGAR (Fr., *Vinaigre*; Ger., *Essig*).—Vinegar is an acid liquid, described in the British Pharmacopœia as prepared from malt and unmalted grain by acetous fermentation. The acid contained in vinegar is acetic acid ($C_2H_4O_2$), and it usually exists in the proportion of 3–6 per cent. The market description of quality is 16, 18, 24. Although the officinal prescription is adhered to by some manufacturers, the use alone of those ingredients is by no means usual; indeed, malt, in many instances, is not in the present day used at all, but for it are substituted artificial glucose ($C_6H_{12}O_6$, H_2O), and cane-sugar or molasses ($C_{12}H_{22}O_{11}$). These latter are very largely used, and as they produce, chemically speaking, the same result, i. e. acetic acid obtained by fermentation, there can really be no objection to their use. In this article, attention will be particularly given to the genuine system of manufacture, viz. from grain.

Grain or Malt Vinegar.—The commencement of the process is similar to that of beer-brewing (see Beverages—Beer, pp. 377–414). The malt and unmalted grain are first crushed (not ground, as it is often erroneously described), between steel rollers, which, revolving against each other, are so fixed that the grains shall be broken only. There are more motives than one for preventing its being ground to meal, the first of which is that great quantities of the husk would find their way into the mash-tun, and would have the effect only of supplying an undesirable amount of unnecessary vegetable matter; secondly, phosphatic combinations are most injurious, and it is in the husk that phosphates abound; while the third objection is a mechanical one, namely, that the bottom of the mash-tun, through which all the wort has to be drawn away, would, on opening the taps, be immediately stopped up. The crushing-mill is shown in Fig. 1434: *a*, tray receiving malt from the funnel above and conveying it to the roller-box *c*, whose bottom is of wire netting, to allow dust to escape; *b*, steel rollers for crushing the malt; *d e*, elevator for conveying crushed malt to the floor above.

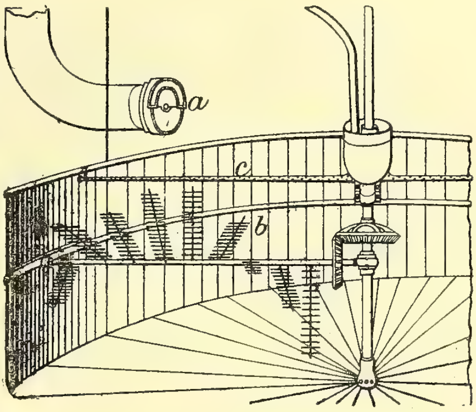
1434.



It may be observed at this point that the unmalted grain (barley, oats, rice, maize, or whatever is chosen) must be thoroughly dried on a proper kiln, previous to crushing, in order that many of the glutinous and albuminoid matters may be destroyed. Unless this precaution is adopted, there is little chance of the vinegar being sufficiently sound to withstand the deteriorating effect of the atmosphere for any time after its manufacture.

After the grain has passed through the crushing-rollers, it is transferred to a receiver (hopper) by means of a belt driven by wheels, and supplied by cups (see Fig. 1434), whence it is passed into the mash-tun, together with water heated to a temperature of about 77° (170° F.). This mash-tun is supplied with revolving forks, which, whilst revolving, move round and round the tun, and are kept in motion for about one hour. At the end of this time, the whole will have become thoroughly incorporated, and the temperature uniform. The forks are then stopped, and the mash is allowed to rest for about three hours, after which the taps are set to draw off the wort. This is immediately conveyed to the boilers, and again well boiled for the purpose of coagulating the albumen. Another quantity of water of the same temperature as the previous is then distributed over the grains by means of sparges, in order to thoroughly exhaust the grains of all their saccharine properties. The mash-tun is shown in Fig. 1435: *a*, channel conveying malt and hot water to the tun; *b*, mashing-forks for thoroughly incorporating the materials; *c*, sparges which revolve rapidly, and supply continuous and regulated streams of water for a second mash.

1435.



The components of malt (see pp. 378–9) are vegetable gelatine, diastase, &c., produced from the gluten of barley during germination, and large quantities of starch, which, in the mash-tun, is converted by the diastase first into dextrine (see pp. 1645–7), and at a further stage into artificial glucose (see pp. 1914–21).

It may now be explained why unmalted grain is used together with malt. Malt possesses much more diastase than is necessary for the conversion of all the starch which it contains, and consequently requires more of that body to be supplied from a raw grain, in order to exhaust itself. It is a fact which has been stated by Ham, and verified by other practical vinegar brewers, that good sound vinegar cannot be obtained from malt alone, and the reason is undoubtedly that the superfluity of diastase remaining in the liquor produces secondary and putrefactive fermentation in the acetifier, which cannot, with any certainty, be prevented. It will be apparent from this explanation that a good calculation should be arrived at as to the proportions in which the grains should be used, and the brewer must be guided by a consideration of the quality and weight of them. The mass being converted into artificial glucose, it is passed through a refrigerator into the fermenting-tun, and yeast is added, the operation of yeast being, of course, to produce fermentation. It is at this point that the process of vinegar-making deviates from that of beer-brewing, for, whereas in the latter it is not desired to convert the whole of the glucose into alcohol, but only to the extent of about half, so that the beer may contain some sugar as well as alcohol, in vinegar-making alcohol is the only practical element required, and the fermentation is therefore forced on to the utmost by large and frequent additions of yeast, until all the sugar has disappeared, and an alcoholic solution remains.

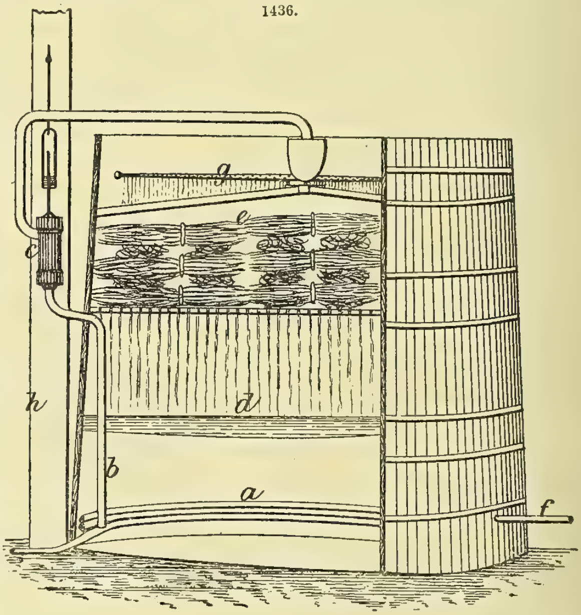
At this point, the chemical change may be described as the conversion of glucose into alcohol, thus:—

$$\overset{\text{Glucose.}}{C_6H_{12}O_6} = \overset{\text{Alcohol.}}{2C_2H_6O} + \overset{\substack{\text{Carbon}\\ \text{dioxide.}}}{2CO_2}$$

The fermentation being now forced to its utmost point, the wort is conveyed by pumps to other fining vats, where it is stored some days to allow it to clear itself, by subsidence, of all dead yeast and cloudiness as completely as possible, and then, passing through a filter-bed of wood-chips and shavings, into the acetifier. This is a large vat capable of holding 8000–10,000 gal., and is constructed as shown in Fig. 1436: *a*, coil of block-tin piping supplied with steam for heating; *b*, intake of pump to feed sparges; *c*, pump; *d*, surface of the article in course of manufacture, above which is a vacant space for dripping; *f*, escape-pipe at bottom of steam-coil; *g*, sparges for distributing finely-divided wort over the birch bed; *h*, support for pump. In the vat, the block-tin worm, constantly supplied with steam, is so regulated by a screw-tap that the wort may be kept at any desired temperature; the pump is made of ebonite, and entering the vat at about one-third from the top, communicates with the bottom, at about 2 in. from the actual bottom, and constantly supplies sparges which throw a continuous spray over a bed of birch. The birch is tied in bundles, and forms a bed about 50 in. deep, below which an empty space about 1 ft. deep is allowed for the wort to drip through. The object is to divide the liquid into as small particles as possible, in order that the oxygen of the atmosphere may have complete and unceasing contact with the greatest quantity.

It is to be pointed out that the birch must be freed of all juice and colouring matter by boiling in several waters, until all odour and colour are exhausted, requiring 3 days before it is sufficiently done; and the twigs must be gathered in the winter, or very early in the spring, before the sap has ascended. The temperature at which the acetifiers are worked varies but little, say 38°–43° (100°–110° F.); in the early part of the process, the higher temperature is applied, and as the acetification proceeds to its completion, it is gradually reduced to the lower. About 6 weeks' continual working is necessary for the complete acetification of each lot.

1436.



At the commencement of this acetifying process, the alcohol is converted into aldehyde in the following manner; first, oxygen of the atmosphere absorbs two atoms of hydrogen from the alcohol, forming water and aldehyde (see pp. 229–30), which latter, being formed, in its turn absorbs more oxygen from the same source, and forms acetic acid (see pp. 5–39). The presence of much oxygen is thus shown to be imperatively necessary, and on its abundance or scarcity depends in a great degree the success of the operation.

Oxygen is also necessary for the commencement of fermentation, but it is not necessary to continue it; fermentation is, however, more rapid and complete in its presence, and even light is a great assistance. It has been satisfactorily demonstrated by Pasteur and others that the exclusion of light greatly retards the fermentation of the wort and the growth of yeast. It is, therefore, advisable to ensure the presence both of oxygen and light, as slow fermentations are frequently unsound, in consequence of the unhealthy condition of the yeast, which becomes exhausted for want of opportunity to grow. This statement is supported by Schutzenberger in the following words, "When pure sugar ferments with a limited quantity of yeast, this becomes exhausted, and at last becomes unfit to effect fresh decompositions of sugar, in the absence of soluble nutritive materials."

The changes and decompositions which occur may be thus described. The first is the conversion by fermentation of glucose into alcohol, thus

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_6O} + \underset{\substack{\text{Carbon}\\\text{dioxide.}}}{2CO_2}$$

Secondly, the conversion of alcohol into aldehyde by absorption of oxygen from the atmosphere, thus

$$\underset{\text{Alcohol.}}{C_2H_6O} + \underset{\text{Oxygen.}}{O} = \underset{\text{Aldehyde.}}{C_2H_4O} + \underset{\text{Water.}}{H_2O}$$

Finally, the conversion of aldehyde into acetic acid by the further absorption of oxygen, thus

$$\underset{\text{Aldehyde.}}{C_2H_4O} + \underset{\text{Oxygen.}}{O} = \underset{\text{Acetic acid.}}{C_2H_4O_2}$$

The peculiar volatile and agreeably aromatic odour and flavour of brewed vinegars, which are not to be met with in those made simply with acetic acid and colouring matter, are due to the presence of acetic ether, and volatile substances of a similar character, derived from the grains used.

The entire process of making malt-vinegar occupies a period of about 2 months, at the end of which time, the vinegar is passed away into other vats for the purpose of cleansing, colouring, and so on. The cleansing (rape) vats are supplied with beds of about 50–60 in. deep, the bottom being a layer of straw, the middle sand, and the upper shingle. Many vinegar-brewers are also British-wine makers, and their rapes are then freely supplied with spent raisins, etc., the refuse of their wine-manufacture, to enrich the flavour of the vinegar.

The natural colour of vinegar is about that of sherry, but as, in England, public taste demands a much darker colour, caramel (see pp. 598–9) is invariably used to produce it.

Formerly, the law allowed the addition of 1 part to 1000 of sulphuric acid ("oil of vitriol") for the purpose of fortifying vinegar (preserving it from decomposition), and it is a prevailing opinion that this is still allowed; but under the Food and Drug Adulteration Act, the addition of *any* quantity constitutes an adulteration.

The Quick German Process.—The "quick German" process of vinegar-making differs only from that already described in the fact that alcohol and water are used in place of the brewed material, alcohol being on the Continent entirely free from excise duty; or alcohol and water with some of the raw brewed wort to convey the volatile and agreeably aromatic odour obtained from the grain, as before explained. The usual strength of the alcoholic solution is about 15 per cent., and this is most convenient for conversion.

Where yeast is not obtainable, an artificial ferment may be produced, which will supply all requirements, by mixing wheat-flour and water into a thick paste, and exposing it, slightly covered and in a warm situation, to spontaneous decomposition, when it will undergo a series of transmutations, resembling the several actions achieved by diastase. The change will commence thus:—The mixture, in addition to converting the starch into sugar, converts the sugar itself into lactic acid, which excites vinous fermentation. About the third day of the exposure, it begins to emit a little gas, and to smell like stale milk; but this odour will soon after change its character, the evolution of gas becoming much greater, and being attended by a new scent, agreeably vinous. This will take place on the sixth or seventh day, and the substance will then be capable of exciting alcoholic fermentation.

The decomposed dough is mixed with a small quantity of tepid water, and applied to a quantity of the wort at 32°–38° (90°–100° F.), when active fermentation will begin in a few hours.

A most interesting and satisfactory experiment may be made by mixing a handful of flour into a thick paste with cold water, covering with paper to shut out dust and permit free access of air, and keeping on the mantelpiece in a warm room, where a fire is burning daily, stirring occasionally. About the seventh day it may be mixed with a mash of about 3 qt. of crushed malt and 2 gal. of warm water, or with a solution of about 10 lb. of glucose in 1 gal. of warm water, when active fermentation will take place, and the beer will be good and sound.

The explanation is that common gluten resembles diastase in the manner of its decomposition, and runs like that substance through two successive dynamic stages, first into lactic and next into alcoholic ferment.

Strong wort may also be set aside for spontaneous decomposition, after the manner of cider or perry making in the apple and pear districts, or of British wine manufacturing, when, after three or four days, it will become turbid, emit gas slowly, create alcohol, and deposit a ferment which acts on saccharine matter. If the wort be weak, however, a scum will collect on the surface, and a brown flocculent substance will be precipitated, which is incapable of exciting fermentation in sugar.

In making vinegar from alcoholic solution, it should not be much more than 15 per cent. in strength, and must be kept warm, say at 32°–38° (90°–100° F.), or at a rather less temperature than that described previously in this article when speaking of the temperature at which the acetifiers should be worked. It is quite unimportant as to whether the spirit used is new or old, and it is impossible to say with certainty what would be the loss of alcohol sustained during the operation. It is not necessary to observe any particular temperature in the rooms where the acetifiers are working, provided that the temperature of the actual article in the acetifier is kept at its proper standard.

The quality of water is also a matter of importance. Good spring water is best, but if that cannot be obtained, river water may be used, which must first be well filtered, to eliminate mechanical impurities. It is found by experience that the silico-carbon filter answers the purpose best.

The operation, watched daily and carefully, should be carried on until the sp. gr. remains constant; this is easily ascertained by the use of the acetometer. The sp. gr. of alcohol is much less than that of water; that of acetic acid, on the contrary, is greater, therefore it may be readily ascertained when the whole of the alcohol is converted.

The consequence of too little treatment would be, of course, that much of the alcohol would be lost, or rather unutilized, through its non-conversion, and the consequent deficiency of acetic acid; whilst on the other hand, if the treatment is continued after the full conversion, a large amount of the acetic acid, being volatile, would evaporate and be lost.

Too much air should not be admitted into the acetifiers, for the reason that it is not necessary, and the evaporation would be extreme; for this reason, as well as for the strength of the acetifier, and comparative facility of cleaning it, the cover of the acetifier should be of wood, instead of cloth or any such material, and the sides should certainly be closed; but a few holes about 1 in. diam. may with advantage be left in the top.

If it is wished to obtain strong acetic acid from vinegar, it should be done by neutralizing with carbonate of soda, lime, lead, or potash, and proceeding to distil with the resulting acetate and sulphuric acid, as described under Acetic Acid on p. 21.

The result, supposing soda to be used, would be explained thus:—

First

$$\begin{array}{ccccccccccc} \text{Acetic Acid in Vinegar.} & & \text{Carbonate of Soda.} & & \text{Acetate of Soda.} & & \text{Carbon dioxide.} & & \text{Water.} \\ 2C_2H_4O_2 & + & Na_2CO_3 & = & 2NaC_2H_3O_2 & + & CO_2 & + & H_2O. \end{array}$$

And second,

$$\begin{array}{ccccccc} \text{Acetate of Soda.} & & \text{Sulphuric Acid.} & & \text{Pure Acetic Acid.} & & \text{Sulphate of Soda.} \\ 2NaC_2H_3O_2 & + & H_2SO_4 & = & 2C_2H_4O_2 & + & Na_2SO_4. \end{array}$$

This process, however, is so expensive and unnecessary that it is never used.

Other Vinegars.—Wine-vinegar and cider-vinegar, sometimes found in the market, are obtained from light French and other Continental wines or from cider, as the case may be, which, turning sour from weakness in alcohol or from exposure, are put to the only remaining use, viz. making vinegar by the quick process, or exposure to spontaneous acetification, i. e. the Fielding process. Vinegar is also made from the vinegar fungus (a fungus which gradually forms on the surface of weak malt-vinegar when exposed to the atmosphere), and sugar and water; the plant is put into milk-warm water, in which sugar and treacle have been dissolved, and the whole is exposed for several weeks in a warm place. The quality of this vinegar is so inferior as to deserve no more than passing notice.

Commerce.—Our imports of vinegar in 1880 were:—From France, 32,683 gal., 3377*l.*; Channel Islands, 29,779 gal., 15,000*l.*; Germany, 12,903 gal., 4854*l.*; other countries, 7466 gal., 1137*l.*; total, 82,831 gal., 10,868*l.* The duty is 3*d.* a gal.

Bibliography.—H. Dussauce, 'Manufacture of Vinegar, and Acetometry' (Philadelphia: 1871); J. Bersch, 'Essig-Fabrikation' (Vienna). H. M.

(See Acetic Acid.)

WAX (Fr., *Cire*; Ger., *Wachs*).

The term "wax" is applied to a number of bodies, of insect, vegetable, and even mineral origin, which bear some resemblance to beeswax, the prototype of the group. Organic waxes resemble fats, in consisting of members of the series of fatty acids both free and in combination (with alcohol radicles), but differ in containing no glycerine; hard at ordinary temperatures, they soften with heat, and melt below 100° (212° F.), burning with a bright flame; they are insoluble in water, slightly soluble in alcohol, soluble in ether, chloroform, carbon bisulphide, and fixed and volatile oils; not readily saponifiable by boiling with potash, and not volatile without decomposition. The characters of earth-wax or ozokerit will be described under that head. The insects which possess the power of secreting wax are comparatively few in number, the principal being two or more kinds of bee, and a few species of coccus or some closely allied genus. Among plants, on the other hand, the production of a wax-like body is a common feature, and the bare enumeration of those exhibiting this property would occupy much space; but the number attaining commercial importance in this respect is limited to less than a dozen genera, and these alone claim attention.

Beeswax (Fr., *Cire d'Abeilles*; Ger, *Bienenwachs*).—This substance is sufficiently familiar as the material with which bees build their cells (see Honey, pp. 1127–30).

In Europe, the production of beeswax is considerable. France was estimated to afford some 27,021 metric *quintals* (of 2 cwt.) in 1873. The yield in the two Greek provinces of Calamata and Messenia in 1880 was placed at 55,000 lb., value 1080*l.* Austro-Hungary exported 7289 metrical centners (of 110¼ lb.), value 772,634 florins (of 2*s.*) in 1877; 5352 met. cent. in 1878, and 2480 in 1879. Venice exported 479½ tons, 113,786*l.*, in 1878; and 469¾ tons, 112,712*l.*, in 1879.

Almost all the countries of Asia figure as large producers. Beeswax is a commodity of great importance in all the islands of the Eastern Archipelago, whence it is exported in large oblong cakes, to China, Bengal, and other parts of the continent. No pains are taken with the bees, which are left to settle where they like (generally on the boughs of trees), and are never collected in hives; their honey is very inferior. Wallace attributes this wax to a wild bee (*Apis dorsata*), whose honeycombs are semicircular in form, and often 3–4 ft. diam. Timor beeswax is reckoned the best of the Archipelago, and is largely imported into Java for the purposes of *batikking*, or tracing patterns on cotton cloth. Beeswax may be procured in almost any quantity at Coti, Borneo; immense loads of it are brought down by the Dyaks to Seboo, where the Cambodian prows purchase it at high prices. That found in many parts of the rajah Selgie's country is perfectly white and beautifully transparent. In 1879, Sandakan exported 226 dol. (of 4*s.* 2*d.*) worth, and Sarawak, 37,330 dol. Lakhimpur (Assam) exported 19¾ tons, value 2112*l.*, in 1871. Hankow exported 325 *piculs* (of 133⅓ lb.), value 2675*l.*, in 1879; Shanghai exported of yellow wax (presumably bees'), 380½ *piculs* in 1878, and 386 in 1879; Canton exported 70¼ *piculs* in 1877 and 39 in 1878 of an undescribed wax, probably bees'; but many of the Chinese ports receive supplies of beeswax and Japan wax from other countries. Of W. Asia ports, Kastamuni sent away 50,000 okes (of 2·83 lb.), value 7500*l.*, in 1879; Brunei despatched 1695 dol. (of 4*s.* 2*d.*) worth to Singapore; and Bushire, 2500 rupees' (of 2*s.*) worth to Java, in the same year. The exports from Aleppo in 1879 were:—12 tons, 1440*l.*, to France; 15 tons, 1800*l.*, Italy; 3 tons, 360*l.*, Turkey; 6 tons, 720*l.*, Austria; total, 36 tons, 4320*l.*; in 1880:—15 tons, 1800*l.*, France; 10 tons, 1200*l.*, Italy; 2 tons, 240*l.*, Turkey; total, 27 tons, 3240*l.* Adana, in 1878, despatched 13,101 *kilo.* (of 2·2 lb.), value 965*l.* The shipments from Mersine [Musyna] in 1879 were:—40 tons, 4800*l.*, to Italy; 38 tons, 4660*l.*, Turkey; 5 tons, 480*l.*, Great Britain; 3 tons, 360*l.*, Greece; total, 86 tons, 14,480*l.*; in 1880:—67 tons, 6420*l.*, Turkey; 48 tons, 4700*l.*, France; 10 tons, 950*l.*, Austria; 2 tons, 192*l.*, Great Britain; total, 127 tons, 12,262*l.* Ghilan exported to Russia, 1346*l.* worth in 1878, and 1731*l.* in 1879.

The countries of N. Africa furnish large supplies of beeswax. The values of the exports from Egypt in 1879 and 1880 respectively were as follows:—Italy, 5900*l.*, 6773*l.*; Austria, 2600*l.*, 3625*l.*; Great Britain, 600*l.*, 1901*l.*; Turkey, 590*l.*, 358*l.*; Greece, 40*l.*, 327*l.*; France, 920*l.*, 23*l.* Tangier despatched in 1879:—250 cwt., 1750*l.*, to Great Britain; 30 cwt., 210*l.*, Spain; 24 cwt., 168*l.*, France; total, 304 cwt., 2128*l.*; and in 1880:—101 cwt., 707*l.*, Great Britain; 98 cwt., 686*l.*, France. The exports from Mogador in 1880 were:—170 bar., 2200*l.*, to Great Britain; 505 bar., 4500*l.*, France; 6 bar., 60*l.*, Spain; total, 1265 *quintals* (of 2 cwt.), 6760*l.* Algiers exported 43,000 *kilo.* (of 2·2 lb.) in 1867, and 113,000 *kilo.*, 300,000 *fr.*, in 1872; later figures were 46,160 *kilo.* in 1877, 68,644 in 1878, 30,087 in 1879. The exports from Madagascar to Mauritius were valued at 2233*l.* in 1875, 1388*l.* in 1876, and 1192*l.* in 1877. Gambia exported 60 tons in 1876, 47 in 1877, and 42 in 1878.

The New York exports were 166,703 lb. in 1878, and 28,662 lb. in 1879. Philadelphia shipped 5883 lb., value 1587 dol., in 1879. Galveston exported 54 packages in 1876–7, and 142 in 1877–8. Chili produces much beeswax, especially in the provinces of Santiago and Colchagua; the exports were 134,511 *kilo.*, value 121,058 *pesos* of (3*s.* 9*d.*), in 1870, and 98,087 *kilo.*, 83,779 *pesos*, in 1874. The Indians on the Orinoco and Amazon collect the wax of a peculiar bee, called *andaquies*, much resembling ordinary beeswax, and having similar local uses. The shipments from San Domingo in 1879 were:—164,000 lb. to the W. Indies, 19,500 Italy, 13,400 Spain, 9500 United States, 7300 France; in 1880:—126,535 lb. W. Indies, 50,400 United States, 42,250 Spain, 37,250 Italy, 4270 Great Britain. The Bahamas exported 97*l.* worth in 1876, 29*l.* in 1877, 15*l.* in 1878, and 89*l.* in 1879.

The approximate London market values of beeswax are:—American, 5*l.* 10*s.*–6*l.* 17*s.* 6*d.* a cwt.; Jamaica, 5*l.*–7*l.* 15*s.*; Gambia and Mogador, 5–6*l.*; Madagascar and Zanzibar, 5*l.*–5*l.* 5*s.*; E. Indian, 5*l.*–6*l.* 10*s.*; ditto white, 6*l.* 10*s.*–9*l.*; Australian and Cape, 5–7*l.*

Beeswax is obtained by melting the combs, after expression of the honey, in boiling water, on which it soon floats; it is left to cool, then remelted without water, and run into moulds of various sizes and forms. In this state, it is known as "yellow" or "virgin" wax, and is used for floors, and for making sealing-wax, lithographic crayons, and mastics. When bleached as described on p. 586, it is employed in candle-making and modelling figures, flowers, and other objects. The quality is mainly judged by the facility with which a sample bleaches; some, as that from the neighbourhood of Bordeaux, can scarcely be bleached at all.

Beeswax is adulterated to a very large extent, and with very numerous substances. Mineral adulterants may be detected by dissolving 1 *grm.* in 5 *grm.* of chloroform, warming if necessary. If a sediment remains, it can be examined to ascertain the constituents; turbidity of the solution when cold indicates a resinous body; milkiness, with transparent globules on the sides of the vessel, points to a vegetable wax. The presence of large quantities of paraffin is revealed by digesting with concentrated sulphuric acid at a moderate heat, by which the wax will be charred and destroyed, while the paraffin will remain floating on the acid; another simple test is the ready and complete solubility of pure wax in boiling concentrated alcoholic potash (1 part potassium hydrate, 3 parts 90 per cent. alcohol), while the paraffin will form a supernatant layer. Stearic acid is detected in the clear chloroform solution on shaking 2 *grm.* suddenly with 12–15 *grm.* of lime-water, when a lime soap forms; also by digesting the suspected sample in a dilute solution of sodium carbonate at a temperature above the melting-point of wax (say 65°–70° [149°–158° F.]). Rosin and Burgundy pitch may be discovered by adding water to a cooled boiled solution of the sample in 1 part water and 2 parts 90 per cent. alcohol, when cloudiness is produced. Vegetable waxes may be detected by boiling a little of the sample (0·3–0·4 *grm.*) in 6–8 *cc.* of water holding 0·5 *grm.* of borax in solution; genuine beeswax forms a clear supernatant fluid, while vegetable waxes produce a syrupy, gelatinous, or stiff mass, according to their proportions. Tallow may be revealed by the evolution of acrolein on boiling in a test-tube.

Carnauba-wax.—The carnauba palm (*Copernicia* [*Corypha*] *cerifera*) is a native of Brazil, growing in prodigious numbers in the province of Pernambuco, and extensively also in Rio Grande do Norte. The fan-like leaves are ranged in a tuft at the top of the hard solid stem; when mature, they are covered with a thin coating of waxy material, for the collection of which they are gathered, and laid on cloths in a cold dry place, when they shrivel and shrink, causing the wax to crack and peel off in small flakes. These flakes are collected, melted in earthen pots, and turned out when cold, forming lumps weighing 3–4 lb. each, and bearing the shape of the melting-pot. In some districts, it would appear that the young undeveloped shoots and leaves are similarly utilized, being cut before they unfold, sun-dried, powdered, and boiled, the wax then rising to the surface, and being easily gathered. The supply is very far short of what it might be. The exports from Pernambuco in 1875–6 were:—To Great Britain, 9138 *kilo.*, 312*l.*; Germany, 9530 *kilo.*, 446*l.*; in 1876–7, Great Britain, 116,872 *kilo.*, 4622*l.*; Germany, 55,108 *kilo.*, 2335*l.*; in 1877–8, Great Britain, 83,530 *kilo.*, 2958*l.*; Germany, 5952 *kilo.*, 210*l.*; 1878–9, Germany, 1542 *kilo.*, 61*l.* The exports from Ceara in 1878 were 5567 *kilo.* to England, and 12,889 to Hamburg. Liverpool imported 80 tons in 1878, 13 in 1879, and 40 in 1880. The market value ranges between 35*s.* and 85*s.* a cwt. Carnauba-wax is rather brittle, of a waxy or resinous lustre, and light sulphur-yellow colour, which, it is said, cannot be removed or destroyed; it melts at 84°–97° (183°–206° F.), according to different authorities, and has a sp. gr. of 0·99. It is largely used as a substitute for and adulterant of beeswax. The tree is valuable for many other purposes, including the fibre of its leaves (see p. 940).

Chinese White Wax, or Pe-la.—This wax is the joint product of an insect (*Coccus Pe-la*) and one or more kinds of tree, according to some, *Fraxinus chinensis*, according to others, *Ligustrum lucidum*, natives of China, notably the province of Szechuan, and in less degree that of Shantung. Whether the wax is an excretion from the insect itself, or an exudation from the tree caused by the punctures of the insect, does not seem to be clearly settled; but the operations comprised in this sort of farming are as follows. In Shantung, especially in the neighbourhood of Lai-yang, in the east, where the trees are plentiful, the insects are bred and the wax is produced in one and the same district; the insects are put out in the spring, the wax is gathered at the end of the summer, and the insects are then collected from the trees and preserved indoors until the following spring.

But in Szechuan, it is found that while the insect breeds most satisfactorily in Keen-chang, the production of wax is far greatest in the department of Kea-ting Foo. These facts are availed of by the wax farmers, who, about the end of April, convey the pregnant and wonderfully prolific females (whose pea-like appearance leads the Chinese to suppose that they are merely eggs) from the breeding district to the wax district. The journey occupies about a fortnight on foot, and has to be performed at night, as exposure to the sun's heat would precipitate the hatching, which must not take place until after the females have been attached to the trees. On arrival, 6 or 7 females are wrapped together in a palm leaf, and attached to the branches, where they soon give birth to innumerable microscopic progeny, and die. The young insects swarm over the twigs of the tree as a brownish film, but avoid the leaves. As they grow, they puncture the twigs in all directions, and the result is an incrustation of white wax.

No care is needed while the insects are on the twigs, as they have no enemy, not even being touched by ants. About the latter end of August, the twigs are cut off and boiled in water, when the wax melts and floats; it is remelted without water, and poured into deep pans, where it cools to a translucent, highly crystalline, brittle, snow-white mass, fusing at 82° (180° F.), and generally resembling spermaceti in appearance. The yield is at the rate of 2–3 *catties* (of 1⅓ lb.) of wax from 10 *taels* (of 1⅓ oz.) weight of females. The average annual value of the crop is said to amount to 650,000*l.* Hankow, in 1879, exported 6943½ *piculs* (of 133⅓ lb.), value 97,997*l.* Ichang shipped 60 *piculs*, 482*l.*, in 1878, and 438 *piculs*, 4156*l.*, in 1879. Newchwang despatched 1100 *piculs* in 1877, 762 in 1878, and 256 in 1879. The exports from Shanghai were 4432½ *piculs* in 1878, and 6542 in 1879. The wax is frequently adulterated, and often contains 15–20 per cent. of water; its uses are similar to those of beeswax, but it rarely appears in European markets.

Cordillera Wax.—The so-called wax-tree or varnish-tree of the Cordilleras (*Elecagia utilis*) is remarkable for the quantity of green waxy matter which is secreted by the stipules that invest the unexpanded buds. This wax is collected by the Indians, and employed by them to varnish boxes, and other objects. For this purpose, it is purified by immersion in hot water; its fragility is then corrected by chewing it until it becomes ductile, after which it acquires a yellow tint, and is ready for the addition of colouring matters.

Fig-tree Wax.—A kind of vegetable wax is obtained in W. and Central Java and in S.-E. Sumatra, from *Ficus umbellata*, the *getah-lahoe* of the Malays. It is manufactured in hard chocolate-coloured lumps, melting at 60°–70° (140°–158° F.), and bleaching nearly white in boiling water; it is used locally for illuminating.

Ibota Wax.—This is attributed by A. Meyer to the influence of an insect which feeds on *Ligustrum Ibota.* It is probably identical with the ordinary Chinese white wax.

Indian White Wax.—This is produced by the female of *Ceroplastes ceriferus*, an insect allied to the *pe-la* of the Chinese, whose product is so largely used for making candles for the Buddhist temples. The Indian insect deposits its wax in small masses upon the twigs and branches of several trees, but more particularly on the *arjun* (*Terminalia Arjuna*); it does not appear to have ever been propagated, nor has the wild product been collected in quantity. Though an article of undoubted value, it would perhaps scarcely repay expenditure of European time and capital; but the natives might surely render its cultivation a very profitable undertaking. The wax is soluble, or nearly so, in boiling alcohol, also in benzine and ether, but only very slightly in turpentine and carbon bisulphide. It is found at many widely-distant points throughout Sirguja, and is abundant, and suitably situated for experimental cultivation, on the *arjun*-trees growing upon the embankment of the Purulia lake.

Japan Wax.—This is afforded by several species of *Rhus*, the most important being *R. succedanea*, which flourishes especially in the W. provinces of Japan, as far as 35° N. lat.; second in order is *R. vernicifera* (see p. 1692), which extends to 38°; and finally *R. sylvestris.*

The cultivated wax-tree (*R. succedanea*) was originally imported from the Loo-Choo Islands, but growers now distinguish 7 different varieties. The tree flourishes in great abundance on the mountainous declivities of the island of Kiushiu, and in the provinces of Higo, Hizen, Chikugo, and Chekuzen, but less plentifully in Satsuma. It is planted along the road-ways, and around the edges of most cultivated fields, except rice-land, when 2 years old, at distances of about 3 ft. between the stems; when set in squares, the interval is doubled. It is kept low by topping, and pruned to a pyramidal shape; propagation appears to be effected by shoots from the root. According to Simon, in the 5th year after planting, each tree gives 4 lb. of berries, 6 lb. in the 8th, 18 lb. in the 10th, 40 lb. in the 12th, 60 lb. in the 15th, and declines after the 18th year; 4 lb. of berries should yield 1 lb. of wax.

The tree puts forth new leaves in April, blossoms in June, and ripens its berries in October–November. The berries are of the size of small peas, united in bunches; the wax is contained between the kernel and the outer skin. The bunches are gathered, sun-dried for a few days, and stored in straw; when sufficiently mature, they are threshed free of stems by means of bamboo flails. The process for preparing the wax much resembles the local method of husking rice. A wooden tilt hammer worked by hand falls into a wooden funnel-shaped trough containing the berries. In time, the husk and pulp of the berries are reduced to powder, while the kernel remains, and can be separated by a sieve. The mass is then dropped piecemeal from a height, a current of air being blown across the path of descent to remove the chaffy husk, which is afterwards collected and worked over again. In Sikok, it is said that a small percentage of inferior wax is obtained by grinding the kernels. The sifted and fanned powder containing the wax is steamed in hempen sacks laid on bamboo wicker-work, placed over a caldron. The sacks and their contents are then subjected to considerable force in wooden wedge-presses, and the wax that escapes is moulded for the market. Sometimes the flow of wax is hastened by the application of a little *ye-no-abara*, the oil of *Perilla ocimoides.* The crude wax forms a coarse, greenish, tallow-like mass, amounting to about 15 per cent. (Simon says 25) of the weight of the berries; it is thus used for making ordinary candles.

For special purposes, the wax is refined in the following manner. It is first melted, pressed through strong cotton sacks, and dropped into moving cold water, by which means it is produced in crumpled thin flakes, ready for bleaching in the sun. With this latter object, it is laid in shallow baskets, 2½ ft. long and 1 ft. broad, placed in long rows numbering some thousands, in the open air. Here it is repeatedly turned, according to the intensity of the sun's heat, sprinkled with water, and melted again if necessary. It is then perfectly white.

For export, it is now often cast into large cubes weighing 1 *picul* (133⅓ lb.), instead of the conventional saucer-shaped cakes 4–4½ in. diam. and 1 in. thick. The chief marts for the article are Nagasaki, Hiogo, and Osaka, whence it is sent largely to China, and in smaller quantity to Europe. The total exports were 1128 tons, 43,128*l.*, in 1874; the total value in 1875 was 37,249*l.*, and in 1877 about 47,250*l.* The London market value is about 57–80*s.* a cwt. for ordinary, and 55*s.*–67*s.* 6*d.* for inferior. It is often largely adulterated with water, which it takes up when melted with it to the amount of 30 per cent. It is extensively employed for making candles and wax matches; its melting-point is 42°–55° (107°–131° F.); when old, it is soluble in boiling alcohol and warm ether, but separates on cooling. The cultivation of the shrub has been commenced in California.

Koga Wax.—This name is given by Meyer to a wax which he attributes to *Cinnamomum pedunculatum*, of Japan; it is softer than Japan wax, and has not come into European commerce.

Myrica-waxes.—Several kinds of vegetable wax are obtained from species of *Myrica*, the most important of which is *M. cerifera*, often called on that account the wax or candle-berry myrtle, though distinct from the true myrtle (*Myrtus*). *Myrica carolinensis* is much esteemed in the S. States of America, *M. caracassana* in New Granada [Colombia], *M. cordifolia*, *M. quercifolia*, and *M. laciniata* in the Cape of Good Hope, *M. faga* in the Azores, and *M. sapida* in China. The fruits of all these species are covered with a waxy coat, which is collected by boiling them in water, and straining the supernatant wax through a cotton cloth. The melting-point is stated at about 48° (118° F.). It is used as a substitute for and adulterant of beeswax, having a greenish-yellow colour; 4 lb. of berries are said to afford 1 lb. of wax.

Ocuba- or Otaba-wax.—Much uncertainty surrounds the origin of this vegetable wax, and there is considerable probability that it is identical with the concrete fat or wax called *bicuhiba* or *acuhiba* (p. 1379), obtained from *Myristica Bicuhiba*. Wiesner is positive on this point. The yield is stated at 18 per cent. of the fruits. The article is not yet known in Europe.

Ozokerit or Earth-wax.—There are many forms of mineral wax, all of which are hydrocarbons, mostly crystallizable, and differing mainly in the temperature at which they fuse. Generally they are met with in or near petroleum sources (see pp. 1433–47), and appear to bear a close relationship to petroleum and coal.

On the southern littoral of Lake Bal-Khash, in Turkestan, large veins of ozokerit have recently been found. Deposits exist at Monte Zolo, not far from Savignano, in the valley of the Samoggia, province of Bologna. A large quantity was lately discovered near Gisborne, New Zealand. A bed measuring 60 miles long, 20 miles wide, and 20 ft. thick has been reported to exist in S. Utah. But Galicia remains the chief source of mineral wax, the working of which deposits is inseparably associated with that of petroleum (see p. 1434). The low price of the liquid oil renders the solid wax much sought after, for which purpose, shallow horizontal levels are driven, the beds of wax often measuring only 1–3 in. thick. Much gas is evolved from the wax in working, necessitating ventilators and safety-lamps. The wax is refined for the market by melting in open or steam boilers, after being washed and cleansed at a loss of 10–30 per cent., and is then moulded in masses of 1–2 cwt. It is obtained at a cost of about 14–18*s.* a cwt., and sells when refined at 22–26*s.* The Boryslav district yielded 325,000 cwt. in 1873, and Wolanka 25,000 cwt. It is further refined, both in Vienna and in Frankfort-on-the-Oder, by means of concentrated sulphuric acid. Its chief uses are in candle-making (see pp. 589–90), for the manufacture of illuminating-gas, and as an adulterant of beeswax; its presence in the last-named article is readily detected by its indestructibility in sulphuric acid, while beeswax is entirely destroyed.

Palm-wax.—This name was given by Humboldt to the wax obtained from *Ceroxylon andicola*, a palm indigenous to the highest parts of the cordillera of New Granada [Colombia]. The wax forms a natural exudation from the trunk of the tree, whose bark is scraped (after felling) for its collection; the scrapings are boiled in water, and the supernatant clean wax is skimmed off. Each tree yields about 25 lb. The melting-point of the wax is 72°–83° (161°–181° F.). It is extensively made into candles for local use, preferably in admixture with tallow.

Petha.—This is a Punjabi term for a waxy substance which collects as a kind of bloom upon the surface of the fruit of the white gourd of India (*Benincasa cerifera*), in sufficient quantity to be collected and made into candles.

WOOL (Fr., *Laine*; Ger., *Wolle*).

Wool forms but a branch of the fibrous clothing of animals known as hair (see pp. 1093–9), and is distinguished from hair solely by being curly and serrated. It constitutes the most important textile material derived from animal sources, and demands consideration both in its commercial and in its manufacturing aspects.

Commerce.—The extent of the commerce in wool in which this kingdom is interested is shown in the subjoined table of our importations of that article in the years 1876–80:—

Countries.	Quantities in lb.					Values in £.				
	1876.	1877.	1878.	1879.	1880.	1876.	1877.	1878.	1879.	1880.
Russia	2,680,527	11,384,569	3,487,461	5,351,930	6,019,122	125,447	528,743	142,691	184,855	235,559
Denmark	2,746,462	2,041,994	1,992,413	2,538,395	2,029,379	151,542	115,855	105,154	106,922	103,361
Germany	8,371,549	9,517,450	4,560,485	4,317,818	7,173,932	577,450	585,292	296,931	261,957	399,735
Holland	3,168,297	1,610,236	2,195,134	2,636,188	2,804,905	201,668	112,404	148,784	110,751	126,601
Belgium	2,891,909	2,695,010	2,774,929	3,709,313	5,034,066	175,106	156,608	162,737	220,536	307,578
France	1,675,527	2,355,810	2,054,159	5,586,605	9,057,016	98,157	124,247	106,773	274,133	444,009
Portugal	1,559,144	1,868,999	1,864,167	1,595,232	2,964,637	76,178	93,172	90,165	70,711	143,624
Spain	6,442	169,848	288,604	399,900	1,576,097	215	5,923	7,960	17,159	62,695
Italy	87,775	64,676	45,535	42,545	320,656	5,221	4,749	2,661	1,497	14,165
Austria	117,342	24,139	21,768	85,245	531,431	5,574	1,150	1,160	3,506	20,468
Greece	560	16,207	36,302	170	99,300	9	603	1,339	7	3,975
Europ. Turkey ..	2,053,713	2,846,923	2,300,503	1,061,788	3,517,822	75,048	107,067	99,834	31,988	117,370
Asiat. „ ..	4,905,433	4,366,701	8,945,364	5,374,726	8,913,789	222,741	193,785	383,562	231,323	368,439
Egypt	3,569,808	4,438,143	2,589,859	2,725,596	2,817,342	142,340	182,849	113,107	107,921	109,105
Morocco	2,190,278	2,879,916	2,521,880	1,093,885	2,954,028	85,094	116,711	97,427	42,764	130,178
China	592,420	473,680	1,220,472	423,854	476,353	20,868	18,112	48,032	17,017	15,869

Countries.	Quantities in lb.					Values in £.				
	1876.	1877.	1878.	1879.	1880.	1876.	1877.	1878.	1879.	1880.
United States ..	343,410	418,509	938,239	190,165	713,085	21,206	23,568	44,571	8,977	34,687
New Granada ..	142,842	..	106,153	174,639	284,689	6,724	..	3,820	7,408	11,296
Peru	3,132,951	3,292,962	2,731,453	2,537,897	1,144,660	156,335	170,479	133,804	98,484	51,871
Chili	227,313	534,249	670,126	1,500,138	1,641,025	15,227	39,602	34,444	60,326	68,973
Brazil	172,230	150,263	2,117	3,619	7,559	6,147	4,624	49	126	292
Uruguay	1,005,450	940,001	771,668	75,661	426,463	47,168	35,480	28,736	3,181	22,100
Argentine Repub.	2,553,258	5,943,034	1,668,245	3,130,738	2,566,527	96,423	209,224	59,891	117,473	97,188
Malta and Gozo ..	112,846	311,977	81,391	21,928	268,166	6,126	14,563	3,045	765	10,607
St. Helena	1,200	10,000	254	7,212	9,531	40	480	12	221	331
Cape	35,424,089	32,912,225	30,670,716	36,726,410	42,226,044	2,376,322	2,224,272	2,060,345	2,267,944	2,761,852
Natal	6,734,228	8,695,553	10,285,232	9,199,884	9,159,795	379,079	518,379	568,111	502,539	479,536
Brit. India	24,453,817	21,566,074	27,032,725	22,202,554	29,190,049	986,672	853,820	1,030,394	773,780	1,123,552
W. Australia ..	2,349,813	2,466,530	2,396,540	2,523,913	2,831,986	142,504	150,039	146,202	157,589	179,833
S. Australia	38,117,850	43,684,778	44,028,326	46,181,518	44,799,118	1,753,618	2,043,939	2,081,538	2,158,932	2,165,858
Victoria	96,930,460	103,351,169	94,340,389	93,655,501	94,512,721	7,188,480	7,486,916	6,598,508	6,614,471	6,507,765
New S. Wales ..	53,445,792	57,651,282	54,534,117	64,059,824	76,965,651	3,317,202	3,533,957	3,290,046	3,800,542	4,722,782
Queensland	14,402,214	13,983,858	15,959,679	14,048,302	13,549,431	848,996	843,907	930,316	816,158	839,130
Tasmania	6,037,883	6,435,573	6,319,080	6,923,363	7,003,007	397,390	419,242	410,680	448,176	436,049
New Zealand ..	52,585,145	53,673,873	58,594,062	60,437,190	60,964,640	2,997,579	3,112,469	3,238,026	3,330,076	3,503,675
Canada	65,980	62,200	406,159	90,982	24,536	2,991	4,514	23,012	3,920	1,420
Falkland Is... ..	854,164	911,259	1,335,798	1,123,444	1,633,971	42,212	45,955	66,557	47,797	75,493

The manufacturing qualities and varieties of wool are more conveniently dealt with under the article Woollen Manufactures (see pp. 2049–57).

WOOLLEN MANUFACTURES (Fr., *Industrie lainière*; Ger., *Wollmanufactur*). The pages of history afford ample testimony that the manufacture of wool was one of the earliest occupations, and probably the first textile industry in which mankind engaged. The early domestication of wool-bearing animals affords presumptive evidence in favour of this conjecture. Though pastoral and agricultural occupations have most likely existed side by side from the remotest times, the former would allow more opportunities for observation and reflection than the latter, whilst the natural covering of the sheep and the goat could hardly fail to suggest its utilization for clothing purposes. Agriculture, on the other hand, would require to be followed for a considerable time before the uses of fibre-bearing plants would be discovered, whilst, from that point, great steps in progress would be needed in the preparation and application of the product before these respective ends could be attained.

The manner in which the evolution of the utilization or manufacture of wool proceeded may easily be conjectured. Sheep and goats, from their comparatively defenceless nature, their large numbers, and the rich and abundant supplies of food their milk afforded, would soonest become subject to domestication. It does not appear that in early days their flesh was eaten or otherwise availed of. The wool annually shed would probably be collected in the first instances by the shepherds, to afford a soft and warm covering whilst tending their flocks at night. This would lead to its transfer for the same purpose to the dwelling-place of the family. As population increased, and nomadic habits were engendered by the necessity of seeking fresh pastures for the flocks and herds of the patriarchal races of mankind, they would be led to leave the plains and valleys, and seek the uplands and mountain plateaux, where pastures remained green and water was abundant during the heat of summer. Here, the normal temperature being so much lower, and that of the mountain plateaux especially being sharp and keen, would render personal clothing welcome, if not a necessity. What so accessible, readily adaptable, and so perfect, as the skins of sheep and goats? Hence their adaptation for clothing and tent purposes, for which uses they have hardly been yet discontinued. Subsequently, the felting property of wool was discovered, probably by observing its tendency to become matted in that manner on certain parts of the animal under peculiar conditions. Amongst the nomadic tribes of Central Asia, felt fabrics are still in extensive use for the construction of tents.

That the textile arts were invented during the prehistoric period, is an undoubted fact, and one that fully accounts for the little that is known of their origin. There are many claimants amongst ancient nations for the honour of their invention, but when the best and most authentic testimony is impartially weighed, it seems to point to the conclusion that the award is due to Egypt. Few persons can be dissatisfied with this result, because that country at the dawn of recorded history was already in the enjoyment of a high degree of civilization. Singularly enough, it is also the only country which gives us tangible proof of the excellence to which the art of spinning and weaving had attained in remotely ancient times. We owe this evidence to the curious custom, prevalent in that country, of embalming the dead, in which process the bodies were swathed in numerous folds of cloth. This cloth is in many instances of the most beautiful texture. It is in all cases composed of linen, and not of cotton, as was once generally believed. Usually it is found torn into strips or filleting, and wound spirally around the bodies. Recent discoveries of mummies of kings belonging to the earliest dynasties that ruled over the country have carried this demonstrative evidence several centuries further back than was previously known. Though the cloths thus singularly preserved are all composed of one textile material, it derogates nothing from the strength of the assumption that at least equal excellence had been attained in the manipulation of wool. We have ample testimony that the sheep was a highly esteemed animal in Egypt, constituting there as elsewhere the chief element of wealth. The utilization of its fleece would be obvious.

Whether spinning or weaving was invented first, is now hopelessly beyond discovery, though the conjecture may be hazarded, with a great probability of truth, that it was the latter. The form it would probably assume would be the interlacing of vegetable reeds obtained from the banks of rivers, which art in some places has survived to the present day. The discovery of a method of making a continuous thread from short fibres, most probably wool, by draught and torsion, would place a highly increased power in the hands of the weaver, and enable him to produce a fabric of greatly enlarged dimensions. The art of spinning is one of the most important developments of human ingenuity, and has probably contributed more to the comfort and happiness of mankind than any other single invention. It would be interesting, if possible, to divine how it occurred. There is a probability that the world is indebted for it to some ancient shepherd boy, who, whilst reclining in the shade with his flock grazing around him, laid hold of a stray lock of wool within reach, and amused himself by pulling it into a light mass; maybe he then began to twist a few of the fibres between his fingers, drawing them out at the same time, and observing that he could thus produce a continuous thread. He may or may not have realized the fact that he had made a great discovery: probably not. Assuming the correctness of this supposition, the first thread was woollen, not worsted—a difference that will be explained subsequently.

At the dawn of the historic period, the twin arts of manufacturing flax and wool rise into view together, showing a parallel advance. At that time, the Egyptians had so far perfected and organized the industry, that rudiments of the modern factory system are discoverable amongst their remains. These are found in the paintings on the mummy coffins and the interiors of their tombs. That wool was one of the materials extensively wrought up into fabrics, scarcely admits of a doubt, and the fact that no specimen of the cloth has come down to modern times probably arises from the certainty that its nature unfitted it for the particular use that has preserved the linen one. With a linen fabric, the dead could be swathed much more firmly and closely than with one of wool, owing to the perfectly extended form of the fibres in the former, whilst the latter can scarcely be freed from its natural curvature. During their sojourn in Egypt, the Israelites acquired a knowledge of the native spinning and weaving as there practised. On their departure, and during their wanderings in the wilderness, it is stated that, on the occasion when contributions were being made for the construction of the tabernacle, the women who were wise-hearted spun with their hands, and brought in the yarn, the blue and the purple, the scarlet and the fine linen, which others were inspired to work up into suitable fabrics. A prohibition issued during the same period incidentally reveals that union fabrics were customarily made even at that early time, for it is ordered that "a garment mingled of linen and woollen shall not come upon thee." The sacred writings, through all the subsequent history of the Jewish nation, afford plenty of testimony to the high development of the textile arts, not only amongst themselves, but also among neighbouring nations, the Egyptians, Assyrians, Babylonians, Phœnicians, and others. In a similar manner, classical writers reveal the condition of these arts amongst the Greeks, the Romans, and their contemporaries, the less civilized nations who successively fell under the influence of their dominion. In a previous article (Linen Manufactures), their progress has been traced, and as the manufacture of wool and flax appear to have always advanced hand in hand, any further detail here would be needless repetition.

The instruments in use were the same for both industries, being the distaff and spindle for spinning, and, as occasion required, both the vertical and the horizontal loom were employed. All improvements that took place subsequently were equally applicable to both purposes, and were adopted by both classes of workers as quickly as the limited means of communication permitted. Coming down to modern times, in which more nicety of manipulation has been attained, a greater divergence in the processes has been introduced, arising from more regard being paid to the essentially different nature of the two materials, wool and flax. During the current century, a great advance has been made in the productive capacity of the woollen industry, owing to the introduction therein, with the necessary modifications, of the remarkable inventions that have distinguished the growth of the cotton trade, and have placed it in a position of such notable eminence. This example has also been of indirect benefit to the woollen industry, by stimulating independent invention, which has not been inconsiderable of late years.

The manufacture of wool, including in this term all cognate fibres, is, after cotton, the most important textile industry of Great Britain. The raw material consumed in the manufacture is chiefly composed of the following:—All varieties of sheep's-wool, alpaca, mohair, goats' hair, and camels' hair; in addition to these, are several minor articles, the most important being shoddy, mungo, and extract, all of which are manufactured wools, produced in a manner to be explained hereafter; and such fibres of vegetable origin (cotton, flax, China grass, rheea fibre) as, with silk and silk waste, are consumed in the production of union goods, and generally form the warp of the fabrics.

The industry is separated into two great divisions, primarily dependent upon: (1) the class of wool, and (2) the method of manipulation. To a certain extent, the first dictates the second. These two are the woollen and the worsted trades, each being subdivisible again into several minor branches.

The woollen industry takes for its raw materials chiefly the fine, short, felting wools, technically denominated "clothing" or "carding" wools, to which are added the manufactured wools: "shoddies," "mungos," and "extracts," the nature of which will be explained subsequently. Along with these, in the formation of union goods, silk, and the several vegetable fibres before named, are consumed. From these, are produced the fine cloths of the West of England, Leeds, and other places, and those of several centres on the Continent; the heavy fabrics of the Huddersfield districts; the tweeds of Scotland and Ireland; and the shoddy cloths of Dewsbury, Batley, and Morley, which include all ranges and qualities, from the finest to the coarsest, and the lightest to the heaviest, for male and female wear.

The worsted division, for its share of the raw materials, claims all the long, or "combing" wools, as they are termed, represented by the wools obtained from the Leicester breeds of sheep and the varieties which have been developed from them. Mohair from the Angora goat, the fleeces of the llama, alpaca, and vicuna, and similar animal products, are also included in this division. These are supplemented by the same class of vegetable fibres and silk as in the preceding division. The product from them consists of an extensive series of light goods, having very numerous designations, but substantially consisting of fabrics that generally may be termed "lustres," "mohairs," "alpacas," "llamas," &c. Union cloths from each of these fibres are also made, silk or cotton, and occasionally other materials, being employed for warps. Bradford is the centre of the district producing worsted goods in all varieties, whose values extend from 3*s.* down to 2*d.* a yd. for low union goods. Formerly Norwich was the centre of a great trade in worsteds, but its importance has been declining for a long time past. Fashion and other causes have also conspired to depress the industry and commerce of Bradford and district during the past few years, so that comparatively little enterprise has recently been exhibited, save in individual cases where efforts have been made to adapt the machinery to the production of the softer classes of fabrics now extensively in demand.

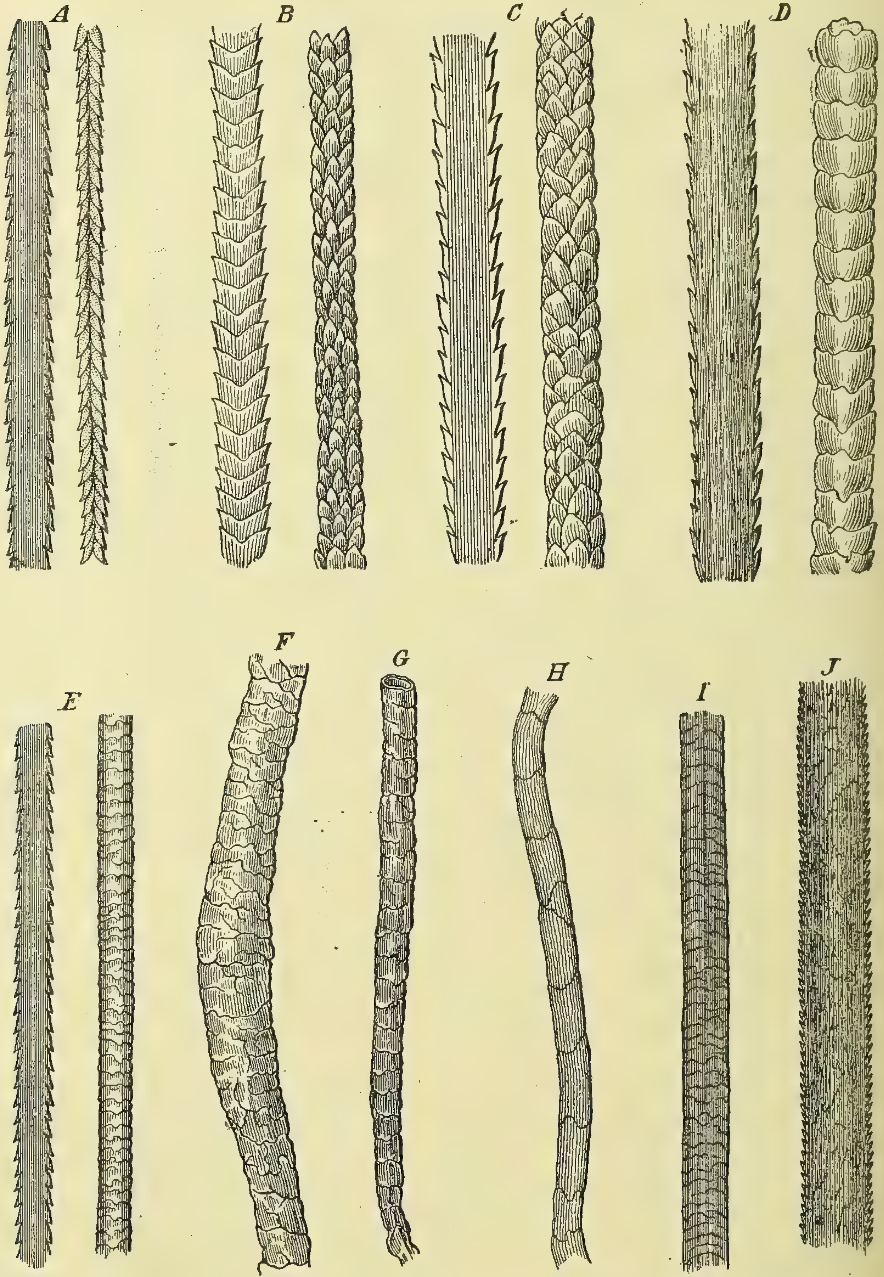
Structure of the Fibre.—The mechanical structure and chemical composition of the wool fibre constitute its most important manufacturing characteristics. In every process during its fabrication into textures, regard must be paid to these, but especially to the first-named; the second, which makes it a bad conductor of heat, is the quality that peculiarly fits it for use as a material for clothing purposes, particularly in temperate and cold climates.

The mechanical structure of the wool fibre always formed the chief basis of its commercial value, even before its true nature was discovered. Though wool has been in use for its present purposes during several thousand years, and its valuable properties have been known for the same time, the peculiar structure on which these properties depend has only recently been discovered. The circumstances connected with this interesting event, which took place on the 7th February, 1835, are fully narrated by W. Youatt, in his valuable treatise upon sheep. In the course of his inquiries, he directed his attention to the nature of wool, in order to discover the cause of its felting property, and called in the assistance of Powell, an artist engaged in the manufacture of the best microscopes known at that time. Their efforts were rewarded with complete success, as the microscope revealed all details of the construction of the wool fibre. The same instrument has been further utilized for the purpose of discovering the minute differences that, judging from the varying effect produced in the manipulation of various kinds of wool, it was inferred must exist. These have been recorded by many inquirers, and the sum of the information thus obtained agrees almost perfectly with the results of experience.

The wool fibre is curly, and to a certain extent elastic. Its surface is covered with scales or imbrications, differing in number and shape according to the species and even variety of the animal from which the fibre has been obtained. The most important differences also exist in the fleece of the same animal, which fact renders necessary the process of sorting. Between wool and hair, the differences are even greater still. In the latter, the scales or imbrications are so imperfectly developed, even if in some sorts they exist at all, that the article until quite recently has been incapable of use in the same way as wool. Recent improvements in the manipulation have, however, led to the successful introduction of hair for purposes of admixture with wool, and its use is now rapidly growing. Those which have been received with most favour, and have, either alone or mixed, been most successfully used, are the hairs of the alpaca, the llama, the vicuna, the Angora goat, and the camel, which are all more nearly allied to wool in structure than other animal hairs. Fig. 1437 sufficiently illustrates the mechanical structure of the wool fibre, and its variations in the different varieties of sheep.

The figures are to some extent typical: A is from a fleece of the celebrated merino variety of sheep, for which the modern world is so deeply indebted to Spain; the characteristics of this wool may be summed up briefly as follows: staple, short; quality, very fine; colour, generally white; most suitable for carding purposes. E is a fibre of Saxony wool, the animal yielding it being a sub-variety of the preceding, a cross between the merino and the best native sheep of Saxony. The wool produced by these animals demonstrates the advantage of high and careful culture, being classed along with Silesian, a similar sub-variety of the merino, the finest wool in the world. Its characteristics resemble those of A. It is sometimes used for combing purposes. The Southdown

1437.



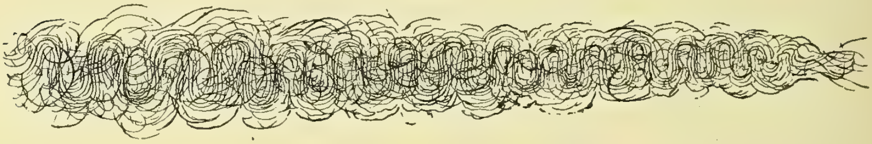
(B), and those breeds of which it forms the basis, constitute a variety of the common sheep. Its wool is in all cases short and fine, except where it has been purposely crossed with long-woolled varieties in order to procure a medium wool. The product is used for both combing and carding. The Leicester (C) and Lincoln (D) represent our long-woolled varieties of sheep. The staple is long, and the quality ranges from coarse to very fine. In Yorkshire, Nottingham, Lincoln, and Leicester, these two varieties yield a highly lustrous wool, approaching mohair (H) and alpaca in brilliancy. These are technically known as "lustre" wools. So far as is known, this wool can only be grown in the four counties above named. When the pure Lincoln or Leicester sheep are transferred to other countries, or even other parts of England, the fleece rapidly loses its brilliancy. Common wool (F), goat-hair (G), cow-hair (I), and human hair (J), are also shown. The carding or short wools are distinguished by a finer fibre and a greater number of imbrications per lineal inch, Saxony and Silesian wools being only $\frac{1}{800}-\frac{1}{900}$ in. diam., 3-3½ in. in length of fibre, and having 2700–2800 imbrications an inch. Merino falls a little below these, and Southdown as much further, the last-named being $\frac{1}{660}$ in. diam., and having only about 2000–2100 serrations in an inch. When a wool fibre has a less diameter than $\frac{1}{500}$ in., it is denominated a coarse wool, and so regarded in the trade; as the length of staple increases, the number of imbrications diminish. These changes render it unfit for clothing purposes, as its felting property is thereby reduced.

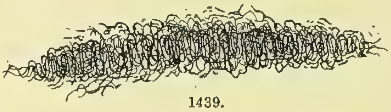
It is believed that the method of growth of the wool fibre is somewhat as follows. The skin of most animals is organically formed for the production of hair, in this term including wool. The length and thickness of the hair is regulated by a law of nature, and is perfectly adapted for its purpose, changing in several respects in the different parts of the body. The shape varies in different animals, but is generally cylindrical or oval. The tip of the hair at first is conical and pointed, this being, as is well known, the distinguishing characteristic of the first or "hogget" fleece of sheep. When left to nature, wool- and hair-bearing animals cast their coat at appropriate seasons, and soon assume a new one. This seems to be caused by a cessation of activity in the secreting glands at their base or root, whereby the hair becomes detached, and is cast off. After a period of rest, the secreting and excreting functions of the glands are resumed, and the new covering soon becomes visible. Domestication of animals, especially when shearing the fleece or clipping the hair becomes habitual, interferes with the natural intermittent activity of the hair-glands, which instead become persistent, and the growth continuous. In the human subject, to which more attention has been given than to animals, and in which the growth of hair is closely analogous, it has been found that at the bottom of each hair-tube is a small conical prominence, like a papilla of the sensitive layer of the dermis, with which latter it is connected by means of the walls of the sheath or hair-tube. This cone is the producing organ of the hair, and possesses a large number of capillary vessels and nerves. The hair-pulp is secreted in this cone, and, being poured out, is first converted into granules, and next into cells, which are subsequently modified to constitute the texture of the hair. The cells contain the pigment upon which the colour depends. In the structure of the hair, a threefold modification of the cells takes place.

Around the central cells, the next layers, comprising the chief thickness of the hair, by a process of lengthening and splitting, common in the economy of cells, are converted into fibres, and quite at the outer circumference a thin circle of cells is flattened into the form of scales, like those of the scarf-skin. The arrangement of these scales is seen in the Merino, Southdown, and Leicester varieties, to be like that of the scales of a fish, though with less perfect regularity, and such differences as result from their being arranged around a cylindrical or oval form. They are the largest and most perfectly developed in the Lincoln, Leicester, and Southdown varieties. In the Merino, the same perfection of arrangement is preserved, whilst they increase in number and diminish in size. Less regularity obtains in the Saxony, though the number further increases. With the larger diameter of the human hair, the scales are still less in magnitude, though greater in number. These observations lead to the conclusion that the order of growth is probably as follows:—(1) The secretion of the fluid obtained from the blood; (2) its discharge from the gland; (3) its conversion into granules, and then into cells distended with fluid; (4) its protrusion to and through the exterior skin, where, on contact with the atmosphere, the outer layers of cells lose their liquid contents by evaporation, the cell-walls collapsing and flattening, so as to form the scales shown in such great numbers. This shrinkage of the cells causes the upper edges of each layer to overlap the base of those of the preceding one, thus composing the beautiful arrangement revealed by the microscope. The shrinkage being simultaneous all round the cylinder which forms the hair, the outer circles of cells form, as it were, a series of cups, the base of the upper one being inserted in the top of the lower one, by which in succession the hair is built up. Each cup is composed of the number of scales or collapsed cells required to form the circumference of the cylinder, and these having been globular, their arrangement in circlets gives the serrated upper edge to each cup. It is this peculiar mechanical structure of the wool fibre that adapts it so admirably for the purposes to which it is chiefly applied, as therein lies its felting capacity.

This, though perhaps its chief characteristic, is not its only one; another of hardly less importance is the spirally curling form of the fibre. Superficially, this constitutes the main distinguishing quality between hair and wool. If a lock of wool be closely examined, each fibre will be seen to be twisted in a spiral direction from the base to the tip. The number of convolutions is greater in the fine or clothing wools than in the long or combing sorts. The processes through which wool is put in manufacturing woollen goods would to a great extent eliminate the curl of the long fibre; but the greater number and the shorter space occupied by the curl of the short wools allows them to be retained, by which means it is admirably adapted for the production of a woollen thread, which has to be fulled or partially felted in a subsequent stage. The more perfect parallelism of the fibres that would result in a yarn made from long wool would prove a great, if not an insuperable, obstacle to the satisfactory performance of the felting process. Figs. 1438, 1439 show this characteristic in both the clothing and combing varieties of wool.

1438.





1439.

The felting quality of wool, though known for centuries, or even thousands of years, was not thoroughly understood until the structure of the fibre was microscopically examined. It may even be questioned now whether the fact is yet fully explained or not. The allegation that it is owing to the short curled lengths of the fibre (when spun into yarn or retained in the mass) offering facilities for an interlocking of the fibres by means of the scales and convolutions, is not quite satisfactory. The theory may fully account for the interlocking or entanglement of the fibres, but it leaves unexplained the principal characteristic of felting, viz. shrinkage. A woollen fabric, when subjected to moisture and warmth, shrinks in every direction in a manner which the mere interlocking of the fibres does not sufficiently explain. The first subjection to this operation does not exhaust the property; it may be repeated frequently, and the article will on every occasion be further reduced in dimension. The introduction of acid into the bath in which the fabric may be dipped greatly accelerates the process, and increases its extent, as is familiarly seen in the manufacture of felt cloths or hats. This is not in any way indebted to the milling process, though working the wool by the hands may be regarded as an equivalent. But this felting or shrinkage takes place without any such action, as, for instance, when cloth is dipped into water and hung up to drain in order to " shrink " it, as the process is technically called, before it is cut up for garment purposes. A similar result ensues, though to a less extent, in the cases of fabrics made from " non-felting " wools, as they are sometimes erroneously termed, when such articles are inadvertently left in water, especially if the water is hot. The same effect is seen in the case of dress fabrics of worsted materials, when the wearer gets caught in a shower of rain. Too often have such materials " run up " to such an extent as to render the dress unwearable afterwards; and partially to this fact may be attributed the present unpopularity of Bradford goods.

It is proverbially easier to offer objections to an accepted theory than to propound a better, but it may be pertinent to observe that experience shows moisture to be essential to felting, and that the process is expedited and carried to a greater extent at a high temperature, or when the water employed is hot. It appears probable, therefore, that the wool fibre is partially dissolved, especially that part which contains the original cells still retaining their contents. The walls of these cells, bursting by the heat or mechanical action, or a combination of both, and their contents being discharged, shrinkage naturally takes place. The scales of the separate fibres, being in contact with one another, or already entangled, the fibres are drawn to each other, as it were, by a firm embrace. Probably also the circlets of scales forming the series of cups of which the fibre appears to be composed may at the same time, and by the same cause, be rendered capable of sliding more deeply one into the other. The pressure being exerted in each direction by the entangled scales of the individual fibres, each of the latter is shortened in a corresponding degree, and shrinkage in every direction results thereby. This conjecture may be held to be supported by the fact that fine wools, which contain the greatest number of imbrications, are the best felting wools.

Varieties of Wool.—Almost every year is adding to the varieties of commercial wool, new kinds being continually introduced, either from new sources of supply, or as the result of assiduous and careful culture. The following table, constructed with great care, and corrected by some of the most eminent wool merchants and experts in this country, has been drawn up and published by Professor Archer, F.R.S.E., and will convey some idea of the numerous kinds of sheep, and the differences in the quality of their fleeces:—

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP.

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
. Spanish (*Ovis Hispaniam* of Linnæus).	Spanish	..	..	..	..	..	..	Used in Leeds and Huddersfield.
	Class 1, Estantes or Stationary.	..	short	fine	black and white.	4–5 lb.	carding	Spanish wools obtained from the plains are of the merino kind, and are chiefly used for woollen goods; but that obtained from the mountains is coarse and of unequal quality, and is used for various low-class goods.
	a. Churrah	..	long (8 in.)	rather coarse.	white	..	combing	
	b. Merino	.. —	short	very fine	white	ram 8 lb. ewe 5 lb.	carding	
	Class 2, Transhumantes or migratory.							
	a. Leonese Negrettes.	..	short	fine	black, white, and grey.	..	carding	
	Escurial or Estremadura.	..	short	finest	white	..	carding	
	Guadeloupe ..	..	short	very fine	white	..	carding	
	Paulars	..	short	good	white	..	carding	
	Infantados	..	short	coarse and hairy.	white			
	b. Sorian							
	Swedish	Merino and native.	long	soft, fine	white			
	French	Merino and Roussillon.	long	soft and very fine.	white	9 lb.		
	Danish	Leonese and native.	medium	fine	white	..	combing and carding.	
	Saxony	Merino and best native.	short	finest	white	..	combing and carding.	
	Prussian	Merino and native.	short	very fine	white	..	combing and carding.	
	Silesian	Merino and native.	short	very fine	white	..	combing and carding.	Silesian wool is almost, if not quite, the finest in the world.
	Hungarian	Merino and native.	short	fine	white	..	carding	
	Hanoverian ..	Merino and small native.	short	very fine	white	ram 4 lb. ewe 2½ lb.		
	New South Wales.	Merino and Southdown.	..	fine	white	2½ lb.	combing or carding.	
	" "	Merino and Leicester.	..	fine	white	3 lb.	combing or carding.	
	W. Australia ..	Merino and Leicester.						
	British (pure breed).	Merino and Southdown.	..	fine	white			
	British (ditto) ..	Merino and Leicester.	..	fine	white			
	"	Merino and other native breeds.	..	fine	white			
. Common Sheep (*Ovis rusticus* of Linnæus).								
ub-variety (*a*), Hornless or Lincolnshire.	Lincolnshire ..	Lincoln and Leicester.	long	good and glossy.	white	8–9 lb.	combing	These are amongst the finest of the long-stapled or combing wools.
ub-variety (*b*), Muggs and Shetland.	Shetland	..	long	very fine	..	..	combing	
ub-variety (*c*), Ryeland.	Herefordshire ..	..	long	medium	white	6–7 lb.	combing	
ub-variety (*d*) Southdown.	Sussex	..	short	fine	white and grey.	3–4 lb.	combing and carding.	Hoggets are valuable, and the long qualities are used in Bradford; the shorter ones in Rochdale for flannels.
	Kent	Southdown and Romney Marsh.	short	medium	white	3–4 lb.	combing and carding.	
	Hampshire ..	Southdown and old blackfaced Berkshire.	short	fine	white	4 lb.	combing and carding.	

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP—*continued.*

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
Sub-variety (*d*), Southdown—*continued.*	Berkshire	Southdown and old blackfaced Berkshire.	short	fine	white	4½ lb.	combing and carding.	
Sub-variety (*e*), Old Norfolk.	Norfolk	Southdown and Norfolk or Downs.	short	fine	white	3½ lb.	combing and carding.	For flannels and low cloth.
		Southdown and Leicester or Norfolk half-breeds.	medium	medium	white	6 lb.	combing	
Sub-variety (*f*), Old Wiltshire.	Wiltshire	Southdown and Wiltshire.	short	fine	white	3 lb.	combing and carding.	
Sub-variety (*g*), Dorset.	Neighbourhood of Dorchester.	..	short	medium	white	3½ lb.	combing and carding.	Livery cloth at Ilminster.
Sub-variety (*h*), Cornish.	Cornwall	Cornish and Leicester.	long	coarse	white	6–7 lb.	combing and carding.	
Sub-variety (*i*), Old Lincoln.	Lincolnshire, Lincolnshire Wolds.	Lincoln and Leicester.	long	good	white	8–9 lb.	combing	
Sub-variety (*j*), Romney Marsh.	Kent	..	long	medium	..	7 lb.	combing	
	Southam, Notts..	Romney and Devon.						
Sub-variety (*k*), Bampton.	Devonshire, Buckland.	Bampton and Leicester.	long	very fine	white	8 lb.	combing	
Sub-variety (*l*), Exmoor, Notts.	Exmoor	Exmoor and Leicester.	long	medium	white	4 lb.	combing and carding.	
Sub-variety (*m*), Cotswold.	Devonshire ..	Cotswold and New Leicester.	long	medium	white	7–8 lb.	combing	
Sub-variety (*n*), New Leicester.	Dishley	..	very long	coarse	white	8–9 lb.	combing	
Sub-variety (*o*), Improved Teeswater.	Durham, York ..	Teeswater and New Leicester.	long	fine	..	9 lb.	combing	
Sub-variety (*p*), Woodland horned.	Lancashire ..	Leicester and Woodland, Southdown and Woodland.	..	..	..	..	..	This breed is nearly if not quite lost.
Sub-variety (*q*), Silverdale.	Lancashire.. ..	..	long	good	white	4½ lb.	combing	
Sub-variety (*r*), Penistone.	West Riding (Yorkshire).	Penistone and Leicester.	short	moderate	white	..	carding	
		Penistone and Cheviot.	short	moderate	white	..	carding	
Sub-variety (*s*), Isle of Man.	Manx Hills ..	..	short	fine	white and grey.	2½ lb.	carding	
	Manx Valleys ..	..	long	fine	..	7 lb.	combing	
Sub-variety (*t*), the higher Welsh Mountains.	The mountain sheep.	..	short	fine	white	2½ lb.	carding.	Chiefly used for flannels.
Sub-variety (*u*), Soft - Woolled Welsh.	The Anglesea ..	..	medium	not very fine.	white	2½–5 lb.	combing and carding.	
Sub-variety (*v*), Cannock Heath or Sutton Coalfield.	Staffordshire ..	..	fair length	medium	white	6–7 lb.	combing	Though generally much discoloured by smoke, it washes quite white.
Sub-variety (*w*), Cheviot.	Northumberland	..	medium	medium	white	..	combing	
Sub-variety (*x*), Dunfaced.	Northumberland, Scotland.							
Sub-variety (*y*), Blackfaced.	Westmoreland, Cumberland, Northumberland, Scotland.	..	medium	coarse	white and grey.	..	combing and carding.	
Sub-variety (*z*), Hebridean.	The Hebrides ..	..	long	inferior	white	..	combing and carding.	
Sub-variety (*a a*), The Orkneys.	The Orkneys ..	..	long	not very fine.	white			
Sub-variety (*b b*), Shetland.	Shetland	..	..	the finest	white	1¾ lb.	carding	
	The Flounder-tailed.	Shetland and Dutch.	long	medium	white	4 lb.	combing	
Sub-variety (*c c*), Wicklow Mountains.	Cottagh	..	short	medium	white	2½ lb.	carding	Used for the flannels of Rathdrum, stuffs bombazines, bombazettes. The Irish breeds have been crossed with Leicesters, Southdowns, and Merinos in every country.
	The Irish	..	long	..	..	3 lb.	combing	

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP—*continued.*

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
Sub-variety (*d d*), Herdwick.	Cumberland Hills	..	short	very coarse	white	3 lb.	carding	Used only for low quality goods. This variety is remarkable for its hardiness and its peculiar sagacity in preparing for a coming snow-storm.
Sub-variety (*e e*), the Rass or Roosh.	Bokhara.							
3. Barwall Sheep (*Ovis Barual*, Hodgson).	Nepal.	.						
4. Hooniah Sheep.	Hooniah or black-faced sheep of Tibet.	..	long	soft and fine	..	..	combing	For ladies' dresses.
5. Cago (*Ovis Cagio*, Hodgson).	Cago or tame sheep of Cabul.	..	long	fine				
6. Seling (*Ovis Selingia*, Hodgson).	Nepal, central hilly region, and Eastern Tibet.	..	long	fine	some breeds black.	..	..	For rugs and coverlets.
7. Curumbar ..	Mysore	..	short	coarse	white, yellow, grey, brown, black.	..	carding	E. Indian wools are chiefly used for making blankets, small quantities also for carpets and rugs, and some of the longest for worsted manufactures.
8. Gārār	India	..	short	coarse				
9. Dukhun	The Deccan ..	..	short	coarse				
10. West Indian	Jamaica	..	short	fine and soft, but mixed with hair.	..	..	carding	
11. Brazilian ..	South American, Pernambuco.							
12. Smooth-haired (*Ovis Ethiopia*, Charlet).	African	..	not used					
13. African (*Ovis Guineensis*, Raii).	Senegal and Sahara.	..	not used					
14. Guinea Sheep (*Ovis Ammon Guineensis*, Schreber).	The Guinea breed.	..	not used					
15. Morvant de la Chine.	China	..	short	rather coarse, but peculiarly soft and silky to the touch.	yellow	..	carding	Blankets, rugs, and carpets.
16. Shaymbliar	India, Mysore ..	..	not used	..	reddish brown.			
17. Zeyla	Zeyla and Mokha	..	..	..	white			
18. Fezzan.. ..	Tripoli and Tunis	..	medium long.	inferior fine.	white and grey.	..	carding	For making caps or fezzes.
19. Marocco (*Ovis Aries Numidæ*, H. Smith).	Marocco	..	short	inferior fine and soft	white and grey.	..	carding	Used for felt goods, blankets, and rugs.
20. Congo Sheep (*Ovis Aries congoensis*, H. Smith).	Congo	..	not used					
21. Angola Sheep (*Ovis Aries Angolensis*, H. Smith).	Angola	..	not used					
22. Yenu, or Goitered Sheep (*Ovis Aries Steatiniora*, H. Smith).	Angola	..	short	fine and close.	..	..	..	Not used in Europe.
23. Ixalus (*Ixalus probaton*, Ogilby).								
24. Cretan Sheep (*Ovis Strepsiceros*, Raii).	Crete	..	short and much curled.	soft and fine.	..	..	carding	
25. Long-tailed (*Ovis longicaudatus*, Brisson).	Russia, Odessa, Crimean.	Russian and Merino.	long	very soft	white			
	Wallachian. Moldavian	..	long	superior, but mixed with hair.	white			
	Greek	..	short, curled.	fine				

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP—*continued.*

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
25. Long-tailed—*continued.*	Barbary	..	hair not used.					
	Donskoi	..	medium	coarse	white and grey.	..	combing and carding.	
26. Broad-tailed (*Ovis laticaudatus,* Erxleben).	Odessa	Merino	short	very fine	white	..	carding	
Sub-variety (*a*), Fat-rumped Sheep (*Ovis stearopyga*).	Tartarian, Indian, Syrian, Chinese, Russian, and South African.	..	long	good				
Sub-variety (*b*), Persian.	Persian	..	long	medium	white, black, fawn, yellow, brown, grey.	..	combing	Used for nusmuds; the unyeaned lamb's skins for pelisses.
Sub-variety (*c*), Fat-tailed.								
Sub-variety (*d*), Aora fiyel.	Abyssinian.							
Sub-variety (*e*), Bokharan.	Bokharan, Caucasian, Persian, and Astrakhan.	..	short	fine and much curled, especially in young lambs.	black and grey in unborn lambs.	..	..	Much prized in the unyeaned state when the delicate grey curled skins are taken and dressed for furs, and the black for making the spots of minever and for wearing as fur.
Sub-variety (*f*), Tibetan.	Tibetan	..	long	soft and fine.	..	..	..	Used for dresses.
Sub-variety (*g*), Cape.	Cape of Good Hope.	..	fur-like, and used as such.	..	..	..	..	As fur for trimming dress, bags, &c.
Sub-variety (*h*), (*Ovis Aries appendiculata*).								
Sub-variety (*i*), Belkah.	Palestine and Plains of Belkah.	..	short	thick	white			
27. Many-horned Sheep (*Ovis polyceratus,* Linnæus).	India and Nepal, The Dumba.							
28. The Pucha ..	Hindostan, Dumba.	..	..	..	..	..	..	None of these is found in our market, according to Archer.
29. Short-tailed	Northern Russia	..	..	..	..	..	..	
30. Sheep of Tartary.	Tartary	..	..	..	..	..	..	
31. The Madagascar.	Madagascar ..	..	short	fine	..	..	..	
32. The Bearded	West African ..	..	hair not used.	..	..	..	..	
Javanese	Java	..	short and finely curled.	white	..	..	..	

This table, though not absolutely exhaustive, is sufficiently full to present in outline a fair view of the varieties of sheep, and the characteristics of many of their fleeces. It will be obvious that no hard and fast line can be drawn between the two classes or great divisions in wool, namely, clothing and combing wools. In the former, there are limits as regards length of staple in those suitable for the first class; for the latter, such requisites as soundness and elasticity. It will be clear, therefore, that within these conditions, are many varieties that will (within given limits) be fit for both uses. The qualities that should distinguish a high-class combing wool have been presented for enumeration as follows:—viz. (1) weight, (2) colour or lustre, (3) length, (4) freeness, (5) fineness, (6) elasticity, (7) softness, (8) soundness, (9) evenness of fleece. These points were submitted as queries to several wool dealers of the greatest experience, who were requested to divide a thousand points amongst them according to their respective values. Soundness and quality, not singly but combined, were reported by these gentlemen to constitute the most valuable attributes of a combing wool. The queries having reference to Australian wools, the estimation chiefly relates to merino wools from that country, in both combing and clothing descriptions. Following are the answers, tabulated according to the queries:—

Combing Wools.	Soundness.	Length.	Weight.	Softness.	Elasticity.	Evenness.	Fineness.	Density.	Lustre.	Total Points.
J. T. Symes and Co. ..	300	250	100	175	50	75	50	..	..	995
Hazard and Caldicot ..	170	170	150	80	90	80	50	60	..	850

Clothing Wools.	Length.	Density.	Softness.	Elasticity.	Evenness of Fleece.	Soundness.	Condition.	Weight.	Fineness.	Total Points.
J. T. Symes and Co. ..	..	150	200	100	100	50	..	100	300	1000
Hazard and Caldicot ..	50	140	80	170	80	80	140	150	..	890

In the preparation of wool for the market, it is desirable, if facilities permit, that sheep should be washed before shearing, because of the dirt and dust adhering to the yolk or grease of the wool. When this is retained, and the wool is packed and shipped in it for distant markets, it is apt to injure the colour, which cannot be restored. All such wool is disqualified for use in the production of fabrics intended to receive fine colours. In washing sheep, the yolk should be entirely cleared, and the sheep allowed two or three days' run, to permit the yolk to rise again to about 20 per cent. of the amount an unwashed fleece usually contains. This gives the wool a soft silky "handle," and maintains its natural elasticity and strength. After shearing, the fleece should be carefully skirted, and all locks, bellies, and stained, burry, and seedy pieces, removed; care ought also to be taken that shanks or kempy hairs are not folded in the fleece. When these parts are removed, the remainder of the fleece will be comparatively free from faults, and consequently all the more valuable.

Wools vary greatly in cleanliness, not only in the percentage of yolk or natural grease they contain, but also in the amount of foreign substances intermixed therewith. These consist of sand, dust, straws, burrs, and other matters, sometimes difficult of removal. The cleanest wools are those of this country; the next in order are those of Germany, France, Australia, Spain, Morocco, Algeria, Turkey, and Buenos Ayres.

Manufactured Wools.—During the past half century, a great branch has been added to the woollen manufacture, and is popularly called the "shoddy trade." Its development is characteristic of the time, which is conspicuous for its efforts to utilize bye and waste, or what were formerly called "waste," products. Many instances of successful results of this kind might be enumerated, but those that properly fall within the scope of this article will amply prove the economic tendency of the age. No sketch of the woollen manufactures would be complete if it omitted a notice of this recent addition to manufacturing industry. Busy centres of population and commerce have sprung up in Yorkshire, entirely based upon this trade, whilst the woollen industry throughout the country has received a great stimulus since shoddy became partly a competitor and partly an aid.

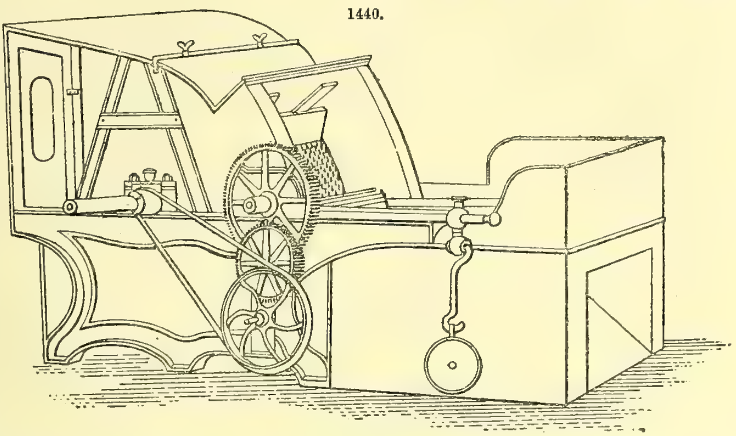
"Shoddy," in its widest sense, means all fibrous materials of animal origin that, having once undergone the processes of manufacture, are recovered from this state by destructive processes, having for their object the restoration of the fabrics to a fibrous condition. Of course, sheep's wool is the chief constituent of the textures so reduced, though fabrics in which the hair and wool of other animals is a principal or subordinate constituent are also included. These recovered wools are divided into three classes, distinguished by the kind of materials from which they are produced, or by the method of manufacture. The first of these is shoddy.

Shoddy.—This includes those recovered wools obtained by pulling into their original fibrous condition all descriptions of worsted and woollen fabrics known amongst dealers as "softs": that is, unmilled fabrics, such as old blankets, flannels, worn-out hosiery. It is difficult to decide to which amongst the several claimants to the invention of this system the credit is justly due. In Yorkshire, it is usually divided between, or rather claimed for, two persons, Benjamin Parr, of Batley, and Benjamin Law. An enthusiastic inquirer, who has devoted considerable time to the investigation, has, however, been led to the conclusion that the world is indebted to a Jew second-hand-clothes dealer in London, during the Peninsular War, when the stoppage of the supply of Spanish wool, and the brisk demand for army goods for the contemplated expedition to Spain (wool from Spain being then used for making them), drove wool to a great price. This man conceived that it would be a paying speculation to tear up old blankets and white flannels by curry-combs, and mix the product with the genuine wool that could be bought in the London market. This was done, and these "doctored" or adulterated bales were sold in Yorkshire for full prices, yielding a handsome profit to the operator. When this outlet for disposing of the product was closed by the decline in the value of wool, the maker offered it in competition with genuine wool for saddlery and upholstery purposes. This inventor's name is not satisfactorily known, but is conjectured to be Davis. The second progressive step in the utilization of this material (its adaptation to the manufacture of cloth) belongs to the above-named Benjamin Law, a small farmer and weaver of Batley, then an inconsiderable moorland village in Yorkshire. Not satisfied with the prices realized for his webs in Leeds, he extended his ventures to London. Being in the city on one occasion, he observed in a saddler's window some material apparently like white wool, but which differed in several respects from any with which he was acquainted. Getting permission to examine it, he found by testing its staple that it would fully answer his requirements. He found the manufacturer and purchased a parcel for himself, which he sent down to Batley, and fully satisfied himself that it was capable of being transformed into useful fabrics. He carefully guarded his secret, admitting only his brother-in-law, the Benjamin Parr before named, to a knowledge of his discovery. These two, having developed the manufacture to some extent, commenced to make the raw material themselves. From this small beginning, after struggling through many difficulties, its use has spread into almost every portion of the woollen manufacture of this and other countries.

Mungo.—The extensive adoption of shoddy as a raw material for cloth manufacture in a few years had the natural effect of rendering all the descriptions of rags from which it was manufactured considerably dearer, and of bringing the price of the product approximately near that of wool. To those who had experience of the originally low cost of both the rags and the product obtained from them, this change was not altogether of a satisfactory nature. There still remained open another source of supply, if only means of rendering it available could be discovered or invented. This was in the rags of milled cloths, both worn-out garments and new snippings from tailors' establishments. These were practically valueless, in most cases being thrown upon the manure heap, whilst from the London tailoring establishments the latter descriptions were obtained at a cost of about $\frac{1}{8}$*d.* a lb., and were usually sold for the purpose of manuring the hop gardens in Kent and Surrey. After Law and Parr had been engaged in the manufacture of shoddy for about 10–12 years, they made an effort to utilize these "hard" rags, as they have since come to be called, as opposed to the "softs" previously described. New snips were procured from London, in order that, if successfully treated, the secret as before might be preserved. The first effort was, however, an entire failure, the machinery which was effectual for "softs" being quite unequal to the task of grinding "hards" into wool. Repeated trials were made, all ending in disappointment, the snips were thrown upon the manure heap, and afterwards carted away to the fields. The idea, though abandoned for the time, was not lost sight of. It is stated that it often occupied the thoughts of, and was the theme of frequent conversation between, Law and Parr. Some few years subsequent to the failure of the above trial, George Parr, a son of Benjamin Parr, observed at a neighbouring flock-manufacturers' workshop (Perrit & Co., Batley Carr), a description of flocks entirely new to him. Upon inquiry, he was informed that the firm were making a new kind of stuffing flocks by grinding up old coats. The young man saw that the grinding process was much more successfully accomplished than had been the case in their own efforts. Purchasing two bags, he sent them home, and made an effort to spin them, but found the cards of the Batley district too coarse for the necessary preliminary operations. Nothing daunted, he had them transported to Morley, to the establishment of John Watson, a manufacturer of fine broad-cloths. Here the efforts were renewed successfully, so far as the production of a thread was concerned; but it was pronounced to be quite useless, owing to the large admixture of cotton threads and linen linings that had been torn up with the cloth. Watson suggested that these should be picked out, and another trial made. This was done, and a more satisfactory result achieved, thought yet far from being such as would justify hopes of a commercial success. The trials were, however, continued by several manufacturers to whom the Parrs offered the materials freely. Successive improvements were made, but in spite of these, progress was slow. Finally the perseverance of the brothers Parr vanquished all difficulties. The article, called "mungo" from an ejaculation of one of the brothers that "it mun go," has since become an important source of supply of raw material to the union woollen manufacture, and to several other branches as well. Fig. 1440 is an illustration of the rag-grinding machine as at present constructed.

Carbonized Wool or "Extract."—A third class of fabrics containing wool yet remained to be utilized. This was composed of the union goods of Bradford and Norwich, in which, as a rule, the warp is of cotton and the weft of wool. The presence of the former in such intimate association made it impossible to utilize the latter to any commercial advantage. In the paper-making trade, the vegetable matter was successfully extracted from these rags by means of caustic alkali, which dissolved the animal fibre, leaving the warp intact. The reverse of this process was suggested by seeing the details of its operation in the Exhibition of 1851. A ship's captain named Corbett is stated to have been struck with the idea that it would be more advantageous to destroy the cheaper and preserve the more valuable fibre. To that end, he is alleged to have commenced

1440.



the study of chemistry, and, after a while, found that a weak solution of sulphuric acid contained in a lead-lined vat, in which the rags were steeped for a short time, completely destroyed the cotton portion, whilst it inflicted little or no apparent damage on the wool. This soon led to the establishment of a manufactory for the production of extract wool on a commercial scale. The inventor found more difficulties in his way than he anticipated. It was looked coldly upon by the Yorkshire trade, who saw that the treatment to which it had been subjected had destroyed its felting properties, and rendered it extremely brittle. New outlets, however, were found for it, and a great demand sprung up amongst carriage builders, saddlers, and upholsterers. As a stuffing material, it was sold largely to the home trade, and was exported to the Continent and America. During the civil war in the latter country, there was an enormous demand for it for army and hospital purposes. In the meantime, the Germans had succeeded in adapting it to textile purposes. Such is one account of this invention. There are, however, numerous claimants for the credit of this discovery, and, as in other cases, in the multitude of assertions it is difficult to discriminate to whom the honour should be rightly awarded.

A claim has been put forward that "extracting" was first discovered and carried on for some time at Rochdale, the inventor in this instance carefully keeping his discovery as quiet as circumstances would permit. This was early in the decade 1850–60. Soon after, a Mr. Crone, of Manchester, suggested the idea to two men who were practically acquainted with the bleaching and finishing processes, as carried on around that town, and by them the process was again discovered, and patented. The original inventor, after some time, bought up this patent, in order to prevent disputes. When the matter became thoroughly known, numbers of people commenced using the process clandestinely, to the disadvantage of the owners of the patent. It is from amongst these that the crowd of claimants has arisen. "Extract" does not appear to have taken that important position in the woollen industries that has been awarded to shoddy and mungo, but it has had a considerable influence in diverting to itself a demand that would otherwise have continued upon the latter articles and pure wools. Its indirect importance, therefore, will be readily recognized.

From the finishing processes of the woollen trade, such as raising, cropping, &c., a considerable quantity of fibrous matter is obtained. These are called "croppings," "cuttings," "shorts," &c., and are the result of the shearing action of a machine employed to cut down the nap of the cloth after raising to a uniform level. This material also has been rendered available for the production of a very useful fabric, especially suited for the sharp winter temperature of such countries as New England, Canada, and Europe. This invention is of American origin, and consists in mixing "croppers'" dust in a strong solution of soap and size, in which a very loosely-woven fabric is then milled; this fabric takes up the short fibres, and can be worked up to any required weight or thickness, and afterwards be finished to a good surface. It is serviceable, durable, and cheap. An Englishman returning from the States is said to have brought back with him a knowledge of the process, which he introduced into Leeds. It has since spread into many other districts of Yorkshire, and other parts of the country where its raw material is plentiful, and has become a considerable industry. The demand for products of this kind outrunning the supply of croppers' dust, in 1873, Ferrar Fenton, of Batley, designed a machine for its artificial production from waste, since which, of course, the supply has been adequate to all requirements.

Processes of Woollen Manufacture.—Wool, in its transformation into woven fabrics, passes through the following processes, which, to save frequent repetition subsequently, are here briefly defined,

(1) "Stapling" or "sorting," which is the division of the fleece into its several qualities.

(2) "Opening" or "cleansing": freeing the wool from dust, sand, dirt, burrs, and foreign substances, and disentangling matted fibres.

(3) "Washing" and "scouring": two processes analogous in method and purpose. The former has for its object the removal from the wool of the dust and dirt adhering to the fibres after the latter operation; also the removal of that portion of the natural grease which, with the preceding matter, is soluble in water. Scouring is a succeeding process, in which the wool is passed through a solution of soap or alkalies and warm water, to remove the portion of the yolk uncleared by the foregoing process. The first is often omitted, and the second is followed by rinsing, the purpose of which is to clear the scouring solution from the wool.

(4) "Drying": to clear the wool from the water acquired in the preceding process.

(5) "Blending": the mixing of the different classes of wools and other fibres from which it is proposed to manufacture fabrics.

(6) "Oiling": lubrication of the wool fibres in order to render them workable.

(7) "Carding": the different stages of this process, scribbling, carding, and condensing, have one purpose, whether conducted with few or more machines, namely, to separate, straighten, cleanse, and mix the materials of the blend, in order to render the resulting yarn thoroughly homogeneous.

(8) "Spinning": woollen spinning performed on the mule.

These complete the processes up to the production of yarn, and now call for notice in detail.

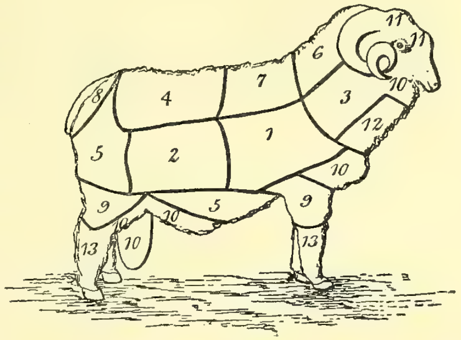
Stapling or Sorting.—Formerly stapling was a separate business, and the person following it was termed a "wool-stapler." This state yet prevails to some extent, but has not grown in a manner corresponding to the development of the woollen trade. In earlier days, the manufacturer resorted to the stapler for the supply of his raw materials. The stapler was a wool merchant, who purchased the wools from the growers, or from importing merchants, and sorted his purchases into various qualities, to suit the requirements of his customers, who thus by his aid were enabled to obtain exactly the quality of wool needed for their productions, without encumbering themselves with a large quantity of wool they could not use, as they must have done when they purchased the fleece from the growers. Thus the wool-stapler's function was a very useful one, and he himself was a highly-respected personage in the fraternity of the industry. But times have changed, and though not entirely superseded, his relative importance is greatly diminished. The increase of wealth, and the growing magnitude of manufacturing establishments have changed to a great extent the old method of business. The woollen or worsted manufacturer can now purchase his wool direct from either grower or importer, his consuming capacity and the variety of his productions enabling him to utilize all the qualities of wool obtained from the fleece.

The wool arrives at the stapler's warehouse or the mill in large bales, each containing about 400 lb. or 80–100 fleeces of wool. Having been weighed and compared with the invoices, the wool is ready for the sorter. Sorting is performed on an oblong bench, the framework of which is of wood, and the top of wirework grating, in order to permit the dust contained in the fleece to fall through. Most fleeces, however, hold a great quantity of dust, mostly composed of the dry epidermis of the sheep, which is so light as to rise and fill the atmosphere of the sorting-room, to the great detriment of the health of the workmen. In order to remedy this, the sorter's bench is now usually enclosed, and fitted with an exhaust fan, so as to prevent not only this light dust, but also much of the poisonous exhalations too often given off by the fleeces of foreign wools especially, from being breathed by the worker.

The sorter, taking a fleece, unrolls it upon his bench, and proceeds to separate it into the required qualities, depositing the different portions in baskets placed beside him for its reception. These baskets vary in number from 6 to 12, or sometimes more, according to the description of the fleece, or the requirements of the manufacturer. Short-wool fleeces, those consumed in the woollen trade, are usually distributed into ten parcels. The "picklock" is the highest quality obtained, and a fleece only yields a very small portion of this quality. The "prime" is the next best, and but slightly inferior to the preceding. Next follow the "choice" and the "super," both very good wools, but inferior to the previous selections. The bulk of the best fleeces are composed of these two classes. The succeeding division is termed the "head" wool, which probably indicates that it is the best of the second or inferior division of the fleece. The contents of the next basket are termed "downrights," a good useful wool, which is followed by the "seconds," the best of the wool from the throat and breast. The next is called the "abb," which is the eighth quality. The ninth is the "livery," and is composed of the skirtings and edgings; the tenth is the "short coarse" or "breech wool," that which comes from the breech of the animal.

These divisions are to some extent arbitrary, and differ according to the requirements of the manufacturer. Fig. 1441 shows the fleece divided into thirteen qualities:—Nos. 1 and 2, the shoulders and sides, always yield the best wool, being long, even, and soft, and the best grown wool of the fleece; the 3rd quality, that on both sides of the neck, is usually a little inferior to the preceding; the 4th, that on the loin and back, diminishes both in length and fineness from the preceding; the upper part of the hind legs yields the 5th quality, the wool in this locality beginning to hang considerably; the upper parts of the neck yield two qualities (6 and 7), both inferior in staple and occasionally faulty; at the root of the tail (8), the wool is more glossy, but coarse; No. 9 is the lower part of the leg, where the grease in the wool is dark in colour, and the staple is more twisted; on the throat (10), there is a great diminution of quality from that of some of the first numbers, the fineness, softness, and curl of the wool having nearly all disappeared, and "kemps" or hairs becoming frequent; the wool of the head (11) is coarse, often harsh, short, glossy, and sometimes dirty; on the lower part of the throat and chest (12), the yield is similar to No. 10, but often shorter, through friction against fences and bars; that from the shins (13) is short, glossy, and coarse, and nearly always very dirty.

1441.



In addition to these, which may be termed permanent qualities of the fleece, there are modifications that arise in flocks, or individuals, the result of differences in the quantity and quality of food and water accessible during growth; or are due to disease or a low condition from other causes. These will occasionally obliterate to a certain extent what may be called the permanent lines of qualities, the whole as a rule suffering degradation. When this occurs in an individual fleece, the sorter may be trusted to keep matters right by the manner in which he will distribute the parts, but when the parcel is faulty in these respects, it must of necessity be put aside for inferior purposes. The rapidity and skill which the sorter displays in the discrimination of the different qualities of a fleece, is a matter of astonishment to the cursory observer.

Washing and Scouring.—The cleansing processes of washing, scouring, and rinsing succeed the operation of sorting. Various methods of cleansing the wool are pursued in different countries, and in different circumstances. Sometimes the wool is first treated to a bath of cold or tepid clean water, for the purpose of removing all earthy matter, and the soluble portions of the yolk. This is succeeded by the scour, in which the wool undergoes a wash in a bath consisting of water heated to 49°–66° (120°–150° F.) or higher according to requirement. This dissolves the natural grease and suint, which form so large a percentage of the weight of the wool, and releases the remaining earthy matter adherent to the grease, and which had resisted the previous process of cleansing. In an examination of the merino fleece, Chevreul found that the raw wool of that breed of sheep consisted of:—Earthy matters, 26·06; suint, 32·74; grease, 8·57; earthy matter fixed by the grease, 1·40; clean wool, 31·23. The proportion of clean wool yielded by other descriptions varies from 25 to 40 per cent., and sometimes rather more; but as a rule, it may be accepted that the processes of washing and scouring will reduce the raw weight by about two-thirds. It is obvious that the removal of this large proportion of the weight will require to be performed with care, in order not to injure the clean fibre, by making it hard or harsh, or causing it to shrink, and thereby injuring its felting properties. This care must be exercised in the selection of the most suitable detergent for forming the scouring bath, the preservation of a proper temperature during the passage of the wool, and the prevention of too sudden a transition from the warm scour bath to the cold rinsing or clearing bath, should cold water instead of tepid be employed in the latter.

Formerly, stale urine was in much request for scouring purposes, for which it was found very suitable, owing to the presence therein of a considerable quantity of carbonate of ammonia, which is a weak alkali, whilst the accompanying organic matters were also useful in protecting the fibre from the action of the stronger alkalies added to the bath. Its insufficient supply, combined with its offensive odour, has greatly diminished its use. Ammonia is also frequently used for the "scour," and that obtained from urine is the best for the purpose. Gas-liquor yields a considerable quantity of ammonia by distillation, but when obtained from this source, it is apt to contain hydrocarbons and sulphide of ammonium, the former of which are injurious to the hands and skin of the workpeople, and the latter damages the wool. Carbonate of soda is another scouring agent, and, in one form or another, is very extensively employed. It is an ingredient, and often the chief one in the special preparations or compounds, retailed in the woollen districts as efficacious wool purifiers. (See pp. 1788–9). Soaps are the most generally accepted scouring agents. In order, however, to employ them so as to secure a satisfactory result, it is imperatively necessary to obtain them of uniform strength. Few articles are more liable to adulteration than soap, as few better hide the sophistication.

Silicate of soda, or soluble glass, has of late years been extensively introduced as a detergent for cleansing wool, and it is stated to have been found to possess valuable properties. Like soap, it holds its alkali in feeble combination. Its detergent power is considerable, and it may be employed alone or in combination with ordinary soap. When used alone for scouring wool, the latter should be well pressed to clear it thoroughly, otherwise the silicate is apt to coat the fibres with a thin film when it comes into contact with the cold water in which the rinsing is performed. Should this occur, dyeing or bleaching of the wool afterwards will be impeded, and the wool rendered more harsh than when properly cleared.

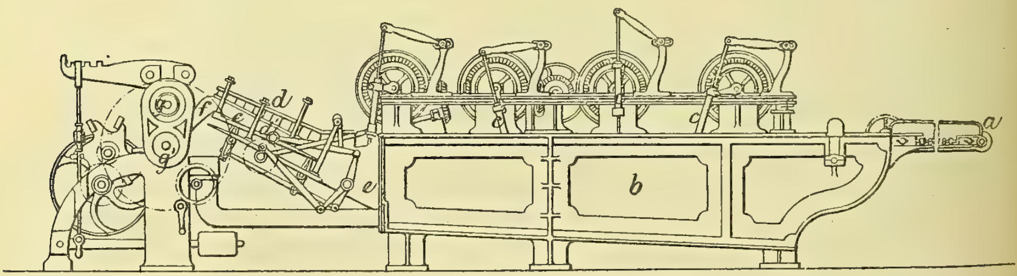
In using soap for scouring purposes, in conjunction with an alkali, soda crystals is the best form if a carbonated alkali is used. A small quantity of powdered double-refined caustic soda, however, can be substituted with advantage in most processes; as compared with soda crystals, not exceeding $\frac{1}{10}$–$\frac{1}{5}$ part of the quantity of soda ash usually employed. It is absolutely necessary that the caustic soda should be free from iron, and that it should be moderately used.

Wool washing is performed by very different methods in different countries. In some, clear running streams are utilized; in others, mill-streams for turning water-wheels, either before or after passing the latter. In other cases, tanks, tubs, or any vessel capable of holding water, are made to do duty for this purpose. A common way, and that perhaps most generally in vogue, is to scour wool in a round tub provided with a false bottom of either wood or galvanized wire. This bottom is usually placed about 9–12 in. from the true bottom, so as to form a cavity for the reception of the sand, dirt, and other matter that the washing releases. The perforations of the wooden bottom or the spaces between the wires are so arranged that, whilst permitting the sediment to pass freely through, the wool is prevented from going at the same time. This bottom is supported upon vertical strips of wood, and is furnished with handles to facilitate lifting it out of the tub when required, in order to cleanse the bottom. The tub is generally about 5 ft. deep and 4–5 ft. diam. The water is heated by means of steam, delivered by a pipe going down the inside of the tub to about 3 in. below the false bottom, and which is furnished with a tap to turn off the steam when a proper temperature has been attained. On the top, and projecting to the outer side so as to form a slope, is affixed a frame having vertical sides about 6 in. high, across which narrow strips of wood may be nailed, or a sheet of galvanized wire extended, to form a strainer or "scray;" upon this the wool is placed to drain after being lifted from the wash, and previously to rinsing in clear water. "Squeezers," or a pair of pressing-rollers usually intervene between the "scray" and the "rinsing-box," but not always. The latter vessel is mostly an oblong box about 5 ft. deep, having also a perforated copper bottom, the holes of which are about $\frac{1}{16}$ in. diam., and as numerous as the strength of the sheet of copper will permit. A copious supply of clean water is required for this vessel, in which, having received its contents, the wool from the scray is immersed and agitated, or passed backwards and forwards by means of a wooden fork, until thoroughly cleansed from the "scour" or suds of the previous bath, and the grease and suint that it has liberated.

The process is to carefully prepare the scouring bath, caution being observed to get it to the proper temperature, for ascertaining which a thermometer should be used. The wool is then placed in the bath in such quantity (but not more than that) as will allow it to be freely agitated, so that every fibre may be fully exposed to the action of the bath. The agitation must be performed in such a manner as not to render the wool stringy, but to keep the mass light and open. The same procedure must be followed and the same care displayed in the rinsing process. If the operation has been properly performed, the wool will leave it in a soft and open condition. Tepid water is always best for the rinsing process, helping considerably to attain the desired ends. By this method, 500–1000 lb. can be washed per diem in one tub.

During the past 20 years, however, much has been done in this country in introducing machinery for the washing of wool. Since its invention, it has moved steadily towards perfection. This has caused it to rise rapidly in public estimation, and, as a consequence, to get generally adopted. There are several makers of wool-washing machines, whose productions leave little to be desired or even accomplished in the way of perfectly performing their work. Fig. 1442 shows one of the best, by J. and W. McNaught of Rochdale, and embodies the latest improvements. The single 4-rake machine here shown occupies a floor space of 24 ft. 9 in. in length by 6 ft. 8 in.

1442.



greatest width over the pulleys. The feed *a* is a travelling apron, upon which the wool to be washed is evenly spread by the attendant, and in that manner passes into the tank *b*, where it is immersed in the prepared bath, and brought within the action of the first rake. The series of rakes *c* are actuated by the bevelled gearing shown, which carries cranks, whose revolutions immerse the rakes at the point of their traverse nearest the back or feed end of the machine, and slowly push them through the liquid, each rake carrying with it the wool that had come within its reach, and delivering it to the next. This slow propulsion prevents the matting or stringing of the fibres, and the felting that would ensue were the action quicker, whilst it is sufficiently quick to thoroughly cleanse the wool by the time it reaches the opposite end of the tank. Here the last rake delivers the wool to the reciprocating harrows *d*. These are frames with rows of alternate prongs on the under side. Each frame moves with its prongs parallel to and nearly touching the inclined plane, and returns over it with its prongs away from and clear of it, in the same manner as the rakes of the tanks retire backwards over the water. The inclined plane is made of polished plate-glass, in order to reduce the friction to a minimum, and consequently the stringing and entanglement of the fibre, whilst the rapid flow backwards of the water brought with it by the saturated wool returns all impurities that might have been brought up therewith into the tank. As one harrow is travelling up the plane with the wool it has received, the other is returning. The washed wool is brought forward by the strokes of the rakes to the bottom of the incline, upon which it subsides within reach of the harrow, which then slides it up. Arriving at the top, it descends by its own gravity, a chute or reverse incline *f*, also of plate-glass, at the bottom of which it comes within the action of the pressure-rollers *g g′*. The prongs of either one or other of the harrows are always acting upon the wool, sliding it forward over the plate-glass surface, neither leaving it until the other has descended upon it, which produces a constant and uniform delivery, preventing all backward slip, which would lead to entanglement.

These machines are easily combined, and made single, double, triple, or sometimes in sets of four. In small establishments, a single machine may suffice, the wool being put through twice; the first time for scouring, the second for rinsing. In large establishments, where a great quantity of wool is consumed, and the best results are desired, the combined machines are used, and the wool is washed, scoured, and rinsed at one operation. In a set of four, cold or tepid water may be used in the first trough, scouring baths in the next two, and again tepid or cold water as may be desired in the last; or any other arrangement may be adopted that skill and experience may devise as likely to yield the most satisfactory result. When the liquor in the first scouring-trough has become unclean, it may be run off, and that from the second made to take its place. For this purpose, the makers have invented a steam-jet transmittor, which causes the liquor when required to flow quickly from one trough to another, thus enabling all the troughs to be placed on one level, instead of at different elevations, as necessitated when the contents are required to flow from one to another by gravitation. The steam used for this purpose is utilized in warming the respective baths. Where it is impossible to arrange several machines in a straight line, the troughs can be made in the form of an elbow, the feeder being at right angles with the delivery.

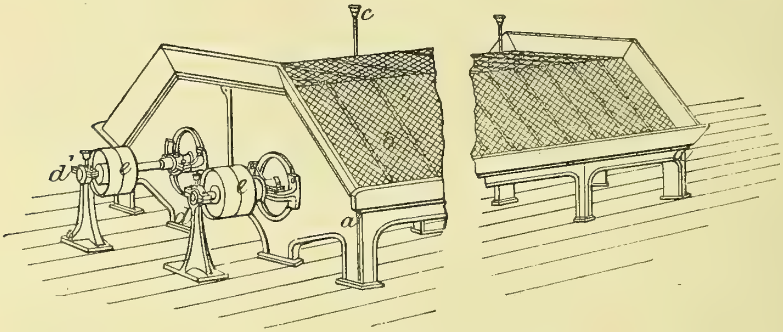
The process of cleansing the raw material is exceedingly important, and when badly performed gives rise to the most unsatisfactory results, the real cause of which frequently passes undiscovered. To secure the end sought, requires the employment of soap uniform in strength, the use of a proper quantity for each bath, the right temperature of the water, care in rinsing, and uniformity in feeding. On no account should the troughs be so filled with wool as to cause the latter to be shovelled forward, as it were, by the rakes; but the supply should be so graduated as to allow each lock to be thoroughly exposed to the cleansing influence of the scouring liquor, and similarly to the clearing action of the rinsing bath at the close. These points require conscientious attendance.

Drying.—Wool which is intended to be dyed passes from the scouring to the dye bath. When this is not the case, it is dried.

The process of drying, as usually performed, is in several respects unsatisfactory. Ordinarily it is spread upon a perforated iron floor over the boilers, when that can be arranged, in order to economize what would otherwise be wasted heat. When this is not convenient, steam-pipes are arranged so as to admit of the wool being laid over them. Layers of wool are then spread over the area in succession, and the wool is dried by exposure in this manner to the radiant heat. It is obvious, however, that when the layer is unevenly spread, which cannot be avoided, the drying will be uneven, and injury to the wool will result. The parts in contact with the floor will dry first, and, if not very carefully tended, will become hard and brittle before the other or upper portion of the layer has been sufficiently dried. The manner in which this is sought to be obviated is by turning the wool frequently and respreading the layer. If carefully done, this prevents much injury accruing, though the evil is not entirely eliminated.

This process, unpromising as it might appear, has also been subordinated to mechanical treatment, and Fig. 1443 represents one of the machines employed for this purpose. As will be seen, it consists of an oblong iron frame *a*, with sloping sides and a flat top. A light iron frame, over which is stretched a covering of strong galvanized iron network *b*, forms the roof. Above this project a number of tubes *c*, forming air-inlets, which are arranged at equal distances from each other in two rows. Two shafts *d d'* extend horizontally through the length of the frame, having bearings or journals of special construction, which are self-lubricating. These journals are placed immediately above each air-inlet. On each shaft, is a series of fans, composed of wrought-iron, and having similar casings or bottoms. These fans draw the air in through the inlets *c*. Inside, are a number of steam-pipes, made of either wrought or cast iron, 2–3 in. internal diameter. The fan-shafts carry fast and loose pulleys *e* for driving.

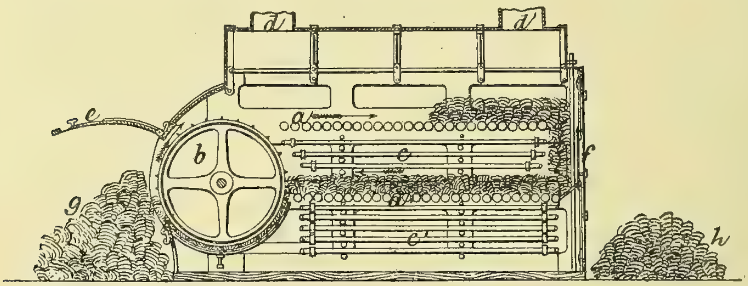
1443.



The process is as follows:—The net-work being covered with a uniform layer of wool, not very thick, the steam is turned into the pipes, and the fans are set to work. These draw the air through the inlets; in its course it comes into contact with the steam-heated pipes, by which it is warmed, and then uniformly discharged through the net-work and the layer of wool. As the heat can be regulated to a nicety, or even cold air be employed, the wool with care never need be overdried or rendered harsh. This machine is also made by McNaught. Its dimensions are 6–9 yd. by 3 yd. It is capable of drying 2000–3000 lb. in a day of 10 hours.

The objections to the antiquated system of drying described above, have also led to the invention of another drying-machine, a longitudinal section of which is shown in Fig. 1444. This differs essentially from the one just described. It is the invention of Moore, of Trowbridge, the centre of the West of England clothing district, and is made by W. Whiteley and Sons, Lockwood, near Huddersfield. Hot air is the agent employed in drying, as in the preceding machine, but provision is made for continually redistributing the wool. The moving parts, omitting cognizance of the driving-gear, consist of two series of rollers *a a'*, and a drum *b* about 4 ft. diam., the periphery of which is covered with small spikes. When working, this drum makes 100–120 rev. a minute. The two series of rollers also revolve, though only at a slow pace, their function being to carry the wool backwards and forwards. As the rollers of each series all revolve in one direction, it is obvious that the wool will be passed from one to another until the end is attained. The rollers are made of iron tubes of about $3\frac{1}{2}$ in. diam., and are set sufficiently far apart to allow of free revolution, the interspaces permitting the circulation of the current of heated air. The revolution speeds of these rollers can be regulated according to requirement. Beneath the rollers, are several tiers of steam-pipes *c c'*, for the purpose of heating the air. At the top of the machine, are two flues or tubes *d d'*, whose extremities are carried outside the building, and are supplied with power-driven exhaust fans, for the purpose of inducing a current through the machine. Each end of the machine is furnished with

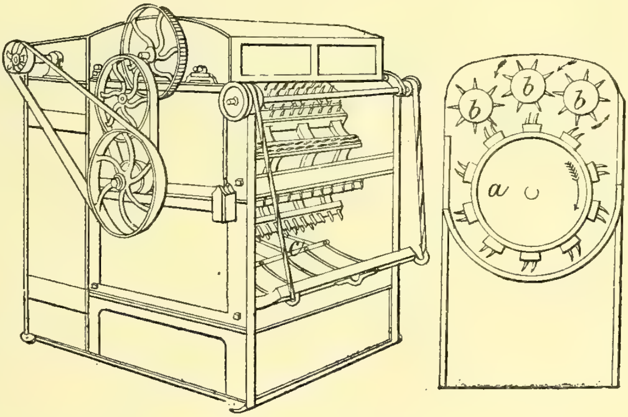
1444.



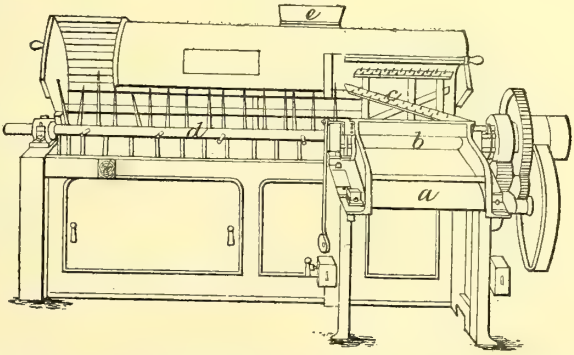
a door. When the process commences, the door *e* over the spiked drum is closed and fastened, and the one at the opposite end *f* is opened for the reception of the charge of wool. The weight usually put in at one time is sufficient to yield about 100 lb. of dry wool. This quantity is placed upon the lower series of rollers, and the door is then closed. By the action of the rollers, the wool is gradually carried forward, until it comes within reach of the spikes of the revolving cylinder, which strike it downward, carry it round, and project it upon the upper series of rollers. Here it commences its return course, and when arrived at the last roller, it falls over, dropping down upon the lower series again, when it recommences and repeats its journey. This is continued for 20–30 minutes, when the charge will be thoroughly dried, and ready for withdrawing. The door being opened, the spiked drum throws out the wool *g*, as shown in the illustration. The heap *h* represents wet wool. The traversing of the wool by the rollers, and its teazing by the spiked cylinder, secures thoroughly uniform drying, whilst the action of the latter also often renders it unnecessary to pass the wool through a teazer before sending it to the card. To facilitate the extraction of dust, dirt, and foreign matter, a grid is inserted in the under portion of the case. About 1500–2000 lb. of wool may be dried upon the machine represented. It is made in various sizes, according to requirement.

Opening.—After being properly dried, the wool is ready for opening, which has for its objects the disentangling of any matted fibres, rendering the whole mass loose and open, so that the fibres can be easily worked or drawn from each other in subsequent stages; and the removal of the dust and impurities that remain after the washing and scouring processes. The "shake willow" or "teazer," Fig. 1445, is the machine usually employed. It is composed of a cylinder *a* having spiked teeth, which usually runs 400–500 rev. a minute. Over the cylinder, workers *b* are arranged, which are actuated by means of the gearing shown on the exterior. These make about 30 rev. a minute. The action of cylinder and workers in combination tears and opens all matted and entangled portions, and releases the dust and foreign substances, permitting the heavier portion to fall through the grid *c* at the bottom. At the back, an exhaust-fan having a rapid revolution draws away the lighter refuse, which is discharged through a tube into the open air. The machine receives its charge through the door formed by the grate, which, being hinged, can be raised or lowered at will. When closed for work, a canvas apron is brought down before it, to confine the dust. When charging, the attendant takes up an armful of wool, and placing it in the machine, closes the door, sets it to work, and allows it to run for the time which experience teaches him the quality or state of the wool will require in order to effect a thorough cleansing. After work has commenced, it is usually charged and fed without being stopped, though the operation is not free from risk, and a little carelessness renders it highly dangerous.

1445.



1446.



Of late years, efforts have been made to improve the common "willow." Fig. 1446 shows one of the most recent attempts to realize this end. In some respects, it is not unlike the conical willow, so well known in the woollen trade, and which was adapted originally from the cotton trade; but it has several important differences. The wool is placed upon the endless apron *a*, by which it is carried to the feed-rollers *b*; behind these, it is immediately seized by the teeth *c* of the teazer, which tear it asunder and open it out. These teeth are set upon bands of iron, arranged spirally round the front part of the shaft, in such a manner as to send the wool forward towards the interior of the machine. This part is constructed so as to form a fan, which, by its action, draws the air forward, and with it the wool, preventing the latter becoming matted or entangled. When the wool has cleared these teeth, it enters the larger part of the machine, where it comes into contact with the beaters, helically arranged upon the shaft *d*. These, whilst the wool is suspended in the air, drive it against the casing of the machine. This casing in the upper part is provided with iron rails, against which the wool is thrown, and further opened without injury. The lower half of the casing consists of a grid, through which the dust and dirt escape. The fore part of the grid, beneath the teazer, is composed of iron bars, whilst that of the length under the beater is of wire network. In the former case, the heavy dust and dirt of dyed wool is shaken out before it comes to the blend, where it would absorb a large quantity of oil. When the wool has arrived at the end of the machine, it is ejected through an opening provided for that purpose. One important addition is the hopper *e* on the top of the case, which will permit the introduction a second time of wool that requires an extra amount of beating, but which might be injured by further teazing, the teazer being avoided at this point. It also serves for introducing wool of a quality that requires no teazing. Mungo and wool may be mixed by the same means. The novel points embodied in this machine entitle it to the notice of manufacturers.

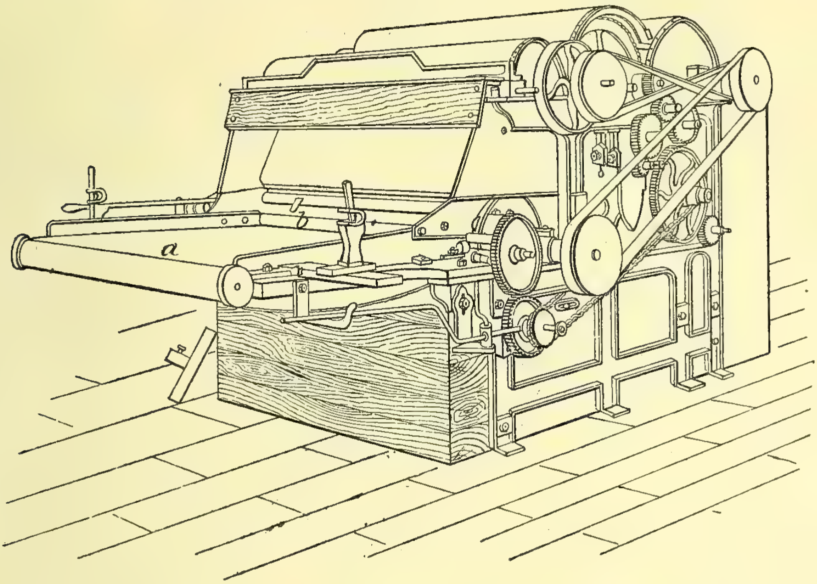
Burring.—Many wools contain a great quantity of seeds, and other matters of vegetable origin, acquired in the pastures in which the sheep have been fed. These are technically termed "burrs," and are often exceedingly difficult to remove, owing to their frequently being covered with sharp hooked prickles or claws, a provision of nature to effect their distribution. These considerably depreciate the value of wool, because of the trouble and cost entailed in their removal. If allowed to pass on to the card, they get broken up, the husks and spines becoming embedded in the yarns and cloth, occasioning much annoyance in the spinning and weaving processes, and ultimately being discoverable in the finished fabric, yielding a sensation as if the manufacturer had wrought into his cloth an infinite number of needle points.

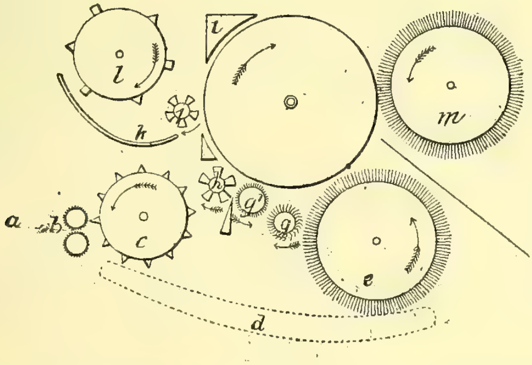
There are two systems of getting rid of this vegetable matter, both of which are effective and highly useful, though not without certain drawbacks. The first is by means of the burring-machine, and the second is by the process previously described as "extracting," by which, in the rags of union textures, the vegetable matter is destroyed, leaving the wool or other animal tissues intact for use again. The extracting process is deemed the best for the class of wools and noils technically denominated "shivey," and which contain broken burrs, small seeds, and motes in considerable quantity, for the removal of which, the burring-machine would not be very efficacious. To some extent, the nature of the wool is injuriously affected by the chemicals used, but this is a minor evil compared with the other, and therefore is the one the manufacturer elects to encounter. Where the "burrs" are of fair size and unbroken, it is preferable to remove them by mechanical means, rather than by the chemical process. The wool is thereby preserved in all its qualities, at the cost of a little trouble and expense.

The burring-machine is represented in perspective and section in Figs. 1447, 1448. It has the usual feed-lattice *a* and rollers *b*, after which comes a beater or fan *c*. Underneath the working parts, a travelling lattice *d* is extended; over its further extremity and in contact therewith, is a roller-brush *e*. The latter works in contact with the large cylinder, which is fitted with a series of steel plates, about 1 in. in width, set closely together, the front edges of which are armed with fine steel needle-like teeth, inserted obliquely, so as to incline the points upward or forward in the direction of the revolution of the cylinder. These teeth do not project above the surface. Beneath the cylinder, are two small rollers *g g′*, the first being clothed with bent card wire, and the second with strong hog-bristles. In close proximity to *g′*, is the burr-roller *h*. Just above the burr-roller, two bars of iron *i* are extended across the face of the cylinder, the sides against the cylinder being concave. These are termed "ledger-blades." Acting in the space between these blades, is another burr-roller *j*, and beneath this is a grid *k*, over it being another large roller *l*, carrying ribs and spikes. On the opposite side of the cylinder, is another large roller-brush *m*, whose function is to strip the wool from the cylinder, and discharge it into a box.

The process is as follows. The wool is fed by hand upon the lattice *a*, which carries it between the rollers *b*, on delivery from which, it is struck downwards in tufts by the beater *c*, falling upon the interior lattice *d*, which carries it into contact with the revolving brush *e*; this conveys it to the cylinder *f*, the needle-pointed armour of which seizes the fibres, but forces the burrs into a prominent position, which subjects them to the strokes of the spiral blades of the burr-roller *h*, sometimes called the "knocker-off." The small card-roller *g* strips the wool from the brush-roller *e*, which happens to escape being taken in the first instance by the large cylinder. This it delivers to the brush-roller *g′*, which in turn gives it to the cylinder. When the wool has passed the burr-roller *h*, it is smoothed down by the concave faces of the bars *i*, after passing the first of which, the burrs that have escaped the first roller are caught by the second *j*, and struck off upon the grid *k*, where they become subject to the action of the large roller *l*, whose function is to beat

1447.





1448.

them through the grid into a receptacle provided for them. The wool now freed from its impurities is carried forward by the cylinder to the brush *m*, which revolving at a greater speed than the cylinder, clears it, and discharges the wool into a box.

The principle of the machine is to open and disentangle the fibres of the wool so thoroughly as to loosen and throw the burrs into a position where they can easily be struck off and discharged by the rollers. The wool that adheres to the burrs can be recovered by the "extracting" process.

Blending.—The wool having got thus far is now ready for "blending." This is the mixing of different qualities together, in order to produce the required result. Where only one kind of wool is used in the process, it is simply spread in layers, and freely sprinkled with oil, when it is considered desirable to oil at this point. "Blends," however, are often made up containing more or less of other fibres than wools strictly so-called. These are analogous animal hairs, shoddies, mungoes, "extracts," cotton, and silk waste. Of whatever the blend is composed, care should be taken to ensure that it shall be so thoroughly mixed that, in the succeeding processes, the incorporation of one fibre with the other shall be so perfect that all distinction between them shall be lost. If this is not accomplished, the yarn will exhibit inequalities of draft, owing to the essentially different nature of the fibres, showing a mass of cotton or other fibre at one place, and wool almost alone at another. In the dyeing and finishing processes, these defects come more strongly into view, after having at each stage proved unsatisfactory in working, and diminished the production. When the blend is composed of both animal and vegetable fibres, this care is doubly necessary, otherwise each fibre is likely to assert the individuality of its nature, and to separate from that with which it was required to blend. To ensure the desired results from the mixtures of fibres differing so essentially as do those of animal and vegetable origin, the amalgamation must be perfect.

In deciding upon the component parts of a blend, regard must be had to the fact that these different fibres do not all require a similar amount of carding, and that an incongruous mixture in this respect will often prevent the attainment of satisfactory results, even when otherwise the most perfect care has been displayed. When two classes of material are required to be mixed, they should harmonize in this respect as much as possible, which will give a chance of obtaining, if not of securing, the production of approximately perfect yarn. Another point to which attention ought to be paid is the fineness to which it is intended to spin the yarn. The capability of the separate fibrous materials of being drawn to this length must be kept in view, and harmony as nearly as possible be established, otherwise the capability of the best portion will be lost in that of the inferior; or if the former is utilized, the lower quality will be thrown out as waste, and the result be costly and unsatisfactory. The end to be sought is to obtain the greatest possible percentage of yarn from the blend, at the least expense in labour; this cannot be done unless regard is had to these points. It is not true economy to overwork a low material, nor to underwork a good one. One fault is equally as bad as the other, though the errors may be on the opposite sides of the line of rectitude.

In blends of different qualities of wools, or of wools and other fibres, one general principle should always guide the proceedings. This should be to spread out a thin layer of one quality on a clean floor over as wide an area as convenience will permit, upon which all the successive layers should be placed equally thinly, and in proper rotation. The batch should be well beaten down with sticks, which will help to blend the materials, and keep the bulk within reasonable compass. When used, the material should be always taken from the sides: drawn down vertically from top to bottom by means of a short-pronged rake. This will secure a thorough intermixture of the mass. To take from the top, it will be obvious would simply be to separate the materials again.

Wool and Silk Waste.—In laying down a blend of wool and silk waste, it is important to see that the silk is cleared from the natural gum, as otherwise it will not easily intermix, and in after processes could with difficulty be retained. Should it afterwards be subjected to warmth and moisture, it is also liable to have its gum partially dissolved, which would cause it to adhere to other portions, and to clog the machinery in an inconvenient manner. The next point of importance is that the silk waste must be of the colour intended for the ground of the fabric, and not that of the relieving mixtures. Should it be intended to produce a gray mixture of say 75 per cent. black and 25 per cent. white, the silk waste must form a portion of the black. The wool before the admixture takes place should always be thoroughly well scoured. The silk waste should be reduced in the fibres as nearly as possible to the length of staple of the wool with which it has to be mixed. The fineness should also approximate as closely as can be attained. The silk portion of the blend being extremely light, it is requisite to have all parts of the carding machinery—cylinders, workers, doffers, and "fancy"—very accurately adjusted, and the clothing smooth and sharp. The doffers should not exceed about 4 rev. a minute, and the "fancy" ought only barely to exceed the rate of the cylinder, so as to work with as little draught as possible, in order to prevent the generation of electricity. Oleine is the best lubricant for this blend, but care must be taken to have it free from acid.

Wool and Cotton.—Blends of wool and cotton are usually for hosiery purposes. In this class of mixtures, the Belgian manufacturers have achieved considerable eminence. With their system, they have successfully mixed all proportions of wool and cotton, reducing the former element until it has become conspicuous mainly by its absence. In each case they have produced useful yarns—at a price with which other spinners and manufacturers have found it difficult to compete. The poorer qualities of course are devoted to the production of low grades of yarns. These have usually been known as "Vigogne" yarns, so called from a Brazilian animal whose fleece partakes of the characters of those of the sheep and the goat.

A high quality of this yarn would be composed of half wool and half cotton. Both materials should be good and sound in staple. The wool ought to be fine merino, and the cotton of long staple and very clean. The wool should be thoroughly cleansed from dust and foreign substances, well scoured, carefully dried, willowed, and oiled. The carding process requires to be carefully performed, the ordinary breaker-card being usually selected. All the parts should be accurately adjusted, the workers put on slow speed, and the clothing perfectly smooth and possessing a good working point, so that the wool on being put through shall be delivered as straight as possible. It should be made into a lap in this process.

The cotton is first put through the opener, and made into a lap. For good work, it is then carded to take out all short or defective fibre, neps, motes, &c., in order to secure a clear yarn. Where this is not essential, the carding may be dispensed with. After carding, the slivers are again put through the opener to facilitate admixture with the wool. The proportions of each are next weighed out, blended together, and again put through the teazer once or twice in order to secure thorough admixture. The slivers are then ready to go through the woollen card and condensor. The result, if the operations are properly performed, will be a clean, level, and thoroughly uniform yarn.

Where the highest results are not wanted, a simpler method is often adopted. The proportions being decided on, and weighed out, the wool is first teazed, then oiled, then teazed again. The cotton is next put through the opener, after which the materials are carefully mixed, each layer being spread out very thinly one over the other until the blend is completed, when the mixed material is taken from the side, and again passed once or twice through the teazer, care being taken each time to further blend the material, when it is brought from the front to the back of the machine, by turning the outside of the mass to or upon the middle, there being a tendency (owing to difference of specific gravity of the two fibres) to separate. The cotton must in no case be oiled, as it will take from the wool all the oil it will require.

Oiling.—The oiling of wool is an important and indispensable process in the manufacture of woollen thread. Its purpose is to cover the scales of the fibre, and make a perfectly even surface, which will allow the fibres to glide over each other without interlocking, and without injury to the scales, in the processes through which the wool has to pass. Insufficiently oiled wool loses much more fibre in its manipulation, and suffers injury to its felting property, thus yielding an inferior article at a higher cost, compared with that obtained from a properly lubricated stock.

The plan of oiling in most general use is the hand process. This is best performed in the following manner. The blend having been properly made, and mixed in the teazer or "fearnought," a portion, say as much as can be conveniently used before considerable evaporation ensues, should be taken and spread over as large an area as convenience will admit of near the back or feed of the machine. The spreading should be in thin and even layers. Each layer in succession should be liberally oiled, and at every second layer the mass should be beaten down with sticks, which serves to bring all the fibres into contact with each other, and so to distribute and ensure a thorough oiling of each. The best instrument for securing an even distribution of the oil is a can having a spout in the form of the letter T, both stem and crosspiece being tubes, the latter perforated with several rows of fine holes, whilst its ends are closed with caps which can be taken off for cleaning. The tubes should be about 1½ in. diam., and the cross-piece 9 in. long. The oil should be strained or filtered through a piece of thin cotton cloth or other material that would take out coarse impurities. When this has been done, the oil-can, being supplied, should be swung backward and forward over the layer of wool, in such a manner as to carefully and evenly distribute the oil, and secure the oiling of every particle. Each layer should thus be oiled in succession, until the whole is completed. When used, the wool, as before, should always be taken from the side of the blend, commencing at the top and drawing downwards. All points considered, this system of oiling gives the most satisfactory results. There are, however, several plans of mechanical oiling, means for accomplishing which are attached to the teazer, fearnought, or carding-engine.

In oiling at the teazer or fearnought, a revolving brush is generally used, which is so arranged as, after taking up oil from a tank, to cast a fine spray of oil amongst the material just before entering the machine. When this system is adopted, it is desirable to again pass the wool through the fearnought, to secure thorough lubrication of each fibre.

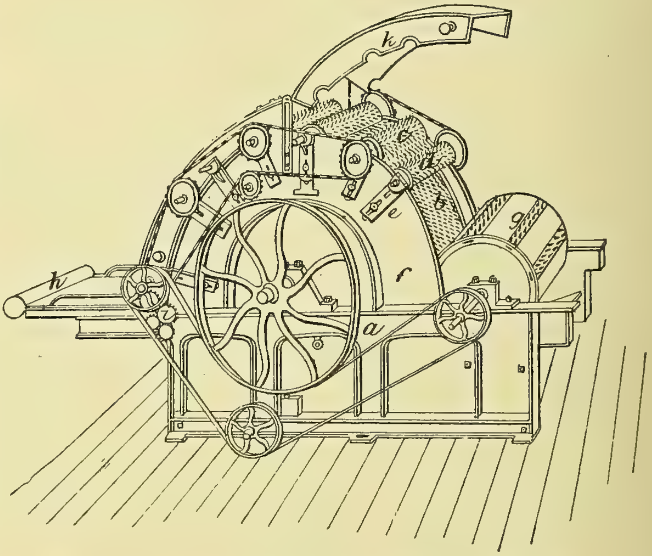
Wool is sometimes also oiled just previously to entering the carding-engine. It is accomplished by a mechanical appliance, similar to that just described. Advantages are claimed for this system over both the preceding, and in theory it is perhaps superior, and affords a better opportunity than either of the others for effecting thorough lubrication. The practical difficulties, however, have hardly been fully overcome. The system is therefore not yet likely to supersede the first-named.

An important matter requiring the careful consideration of manufacturers is the kind and quality of oil to be used in this operation. The object of oiling, as previously stated, is to cover or sheath the scales on the surface of the wool so as, in the first instance, to prevent their becoming entangled with each other in the working process, which leads to great waste of its fibre and damage to that which is not lost, whereby it is injured in its felting properties; in the second, it is to preserve the latter quality intact for utilization in the fulling process. It will be obvious that other fluids would serve equally well, could they be retained by the wool for a sufficient length of time to permit the latter to pass through the machinery. Accordingly, numerous compositions are offered in the market as cheap substitutes for the more costly oil. As a rule, however, oil maintains its position in the estimation of the trade as the best and most economical lubricant, all circumstances being considered, though there are cases in which some of these compositions may be advantageously used.

A good quality of oil, very pure and free from acids, is the best, as it is retained the longest by the wool, and does no injury to the card clothing, nor to the colour of the material. The nature of the wool being worked will, to a certain extent, always influence the selection of the oil, but apart from this consideration, experience has shown that oleine is a cheap and very satisfactory lubricant. It is expressed from animal fats, and is specifically known as tallow-, lard-, and neat's-foot oils (see p. 1367). A recent writer on the subject advocates the oleine obtained as a bye product from the manufacture of stearine candles (see p. 585). But should the oil not be cleared from the sulphuric acid used in its preparation, the card clothing will be injured, the felting property of the yarn will be damaged, and the operatives who have to handle the wool will suffer in their hands and arms, the acid often destroying the finger-nails. Commercial oleine always contains less or more acid, the quantity varying from ½ per cent. upwards. Red oil is of a kindred nature to the above, and is usually similarly contaminated with mineral acid. A ready way of testing oils for mineral acids is to place a drop on blue litmus paper, which, if only a faint trace of acid be present, will turn red.

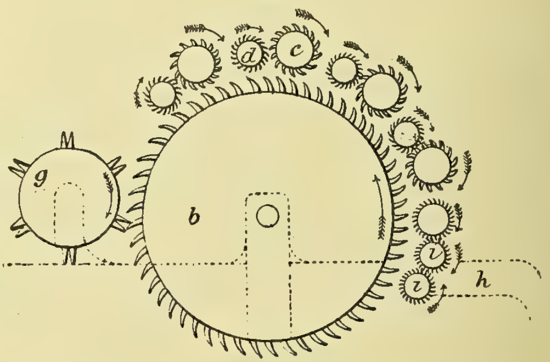
Of the compositions used, the following are regarded as good:—(1) Take of oleine 10 per cent., and boiling water 15 per cent., of the weight of the wool to be oiled; mix, and add a little sal ammoniac, sufficient to cause the oil and water to combine, after which it is ready for use. (2) Pour into a trough or tub 20 parts of oil, 10 parts liquid ammonia, and 5 parts water; mix with a wooden stick, inject steam, and allow the liquid to boil until the strong smell of the ammonia has evaporated; the mixture may then be applied in the ordinary manner. This latter is stated to be a useful and economical lubricant, giving uniform results, and neither injurious to the colour of the wool nor to the card clothing.

1449.



Lard and olive oil are, however, always the most reliable, and generally used when the best results are desired. The quantities greatly depend upon the state of the wool, but it will be found that 4–6 qt. per 100 lb. will ordinarily be sufficient. Where the blend, however, contains a proportion of mungo and cotton, this quantity will require to be exceeded.

1450.



The "fearnought," Fig. 1449, is the last machine employed in the opening process, and is used to perfect the work of the teazer in opening out the tufts or locks of wool, in order to facilitate the work of the carding-engine. It is composed of the framework *a*, containing the cylinder *b*, which is usually 45–50 in. diam., and makes 150–200 rev. a minute. Its surface, composed of wood, is covered with rows of iron teeth 1 in. long, and in shape like a dog's tooth, extending across the face, and set about 1 in. apart. The teeth of each row alternate with those of the preceding one. The small rollers, shown in detail and in section in Fig. 1450, *c*, are denominated workers, and generally revolve about 20 times a minute. The small rollers *d*, alternating with the workers, have a greater surface speed than those rollers, their function being to strip them. Both workers and strippers are clothed alike with one kind of teeth, set in a similar manner to those of the cylinder. The workers and strippers are carried upon bearers *e*, attached to the bend *f*, and a corresponding one on the opposite side. By means of the bearings *e*, the workers and strippers can be adjusted to each other and to the cylinder, according to requirement. The cylinder *g* is a fan, across the face of which are fixed bars of wood, each carrying two rows of straight iron teeth. At the back of the machine is the feed-apron or travelling lattice *h*, on which the wool is placed, and carried to the feed-rollers *i*. The direction of the arrows shows the course of revolution of the rollers. In operation, the rollers are all enclosed in a sheet-iron casing, which is continued underneath, and there perforated, to permit of the dust dropping out, whilst all fibre is retained. Its enclosure also enables the fan to develop and maintain a current of air.

The arrangement of the different rollers in this machine is on the same principle as prevails in all the carding processes, of which it may be called the first stage. The bottom feed-roller is set so that its teeth shall cut as it were into the circle formed by the extremity of the teeth of the cylinder to a depth of about $\frac{1}{8}$ in. The top feed-roller, whilst set back from the cylinder, must similarly work into the bottom one. The first stripper is set so as to clear the top feed-roller, which it does by its quicker revolution, and must be set to within $\frac{1}{8}$ in. or less of the face of the cylinder, so as in turn to be cleared by it. The workers must be set so as to dip their teeth about $\frac{1}{8}$–$\frac{1}{4}$ in. into those of the cylinder with which they must alternate; and each stripper must be set to take the wool from its respective worker, and, at the same time, return it to the cylinder. The course of revolution in each case is indicated by the arrows, and the particular effect is obtained in a great degree from the different surface velocities.

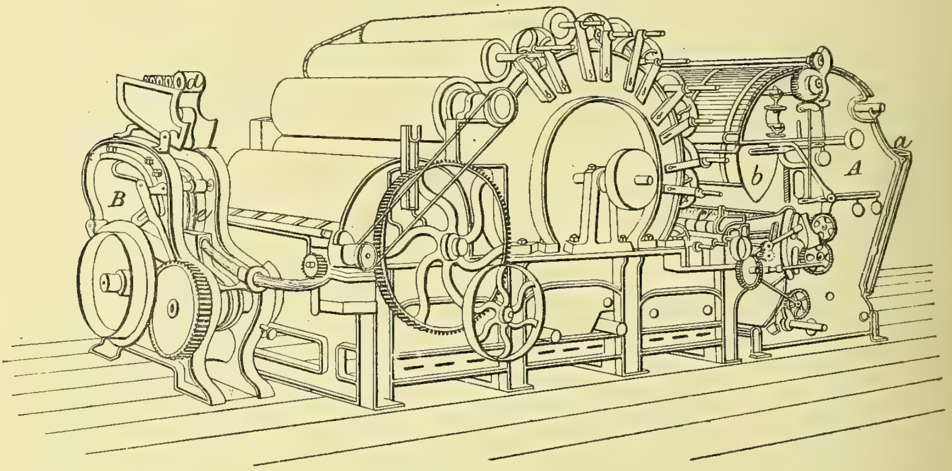
The operative takes the wool as received from the oiled blend, and feeds it by hand upon the travelling lattice, which carries it to the feed-rollers. Passing through these, it is seized and carried upwards by the teeth of the cylinder, some portion however being struck into the upper feed-roller. This is stripped by the first stripper working into that roller, and given over to the cylinder. The wool which the cylinder has already obtained is carried upward with great velocity, but is soon arrested by the first worker, which, though revolving in the same direction, does so at such a diminished rate of speed that it takes the wool from the cylinder into its own possession; but carrying it round, the worker is immediately relieved in turn by the stripper, which is revolving at a greater speed. The stripper instantly gives it back to the cylinder. The wool is again arrested by the next worker, when it follows the same course as in the last case. This is repeated until the series is gone through, when the wool will have been sufficiently opened to fit it for the carding-machine. From the last stripper, the cylinder carries it forward to the fan, which, revolving at a quicker rate than the cylinder, clears the wool therefrom, and throws it out at the front upon a sheet laid to receive it, and in which it is tied up and carried to the carding-room.

Scribbling, Carding, and Condensing.—These processes are simply stages of one and the same thing, namely carding. Up to this point, the operations have been designed to free the wool from dust, grease, burrs, &c., and to open the felted or matted portions. The machinery employed has been of a character appropriate for the work, the clothing of the various rollers, cylinders, &c., having been rough and strong. Scribbling and carding are intended to perfect this work, accomplishing by finer instruments that which the rough ones could not achieve. The entangled locks of wool are now separated fibre from fibre, the curls or undulations of the wool are straightened out to some extent, and the blend is more thoroughly intermixed than before, the whole being reduced to a perfectly homogeneous condition.

Carding machinery is usually arranged in "sets," one set being those machines which perfect the preparation of the wool for the spinning process. Usually in this country, or rather in the Yorkshire woollen districts, the set is composed of two machines, the scribbler and the carder with its condensor attachment. In some districts, of which New England (U.S.) may be cited as an instance, the set is composed of the scribbler, intermediate, and condensor. Where the best results are required it is necessary to use the three, or at least it may be regarded as advisable. There are many variations of form, and different systems of feeding these machines. It is not needful to describe these in detail; therefore a selection will be made of the most recently improved or perfected.

The English system of wool carding for the production of woollen yarn is perhaps as perfectly illustrated in the set of machines constructed by the firm of John Tatham and Co., of Rochdale, as by any now in the market. Good carding is to a great extent dependent upon regularity and evenness of feeding. This was previously and is now widely performed by manual labour, the process being to weigh a given quantity of wool, and spread it equably by hand over a measured space of the feed-lattice. A good result is thus entirely dependent upon the conscientious performance of duty and the skill of the labourer: qualities that are not always to be had. The difficulty of securing them has led, as in many previous instances, to the invention of an automatic method of weighing and feeding the scribbler-card. This is of American origin, and is named the Bramwell automatic feed. By this invention, results are achieved surpassing in quality the best efforts by hand. The machine forms an attachment to the carding-engine, and is shown at A on the right of Fig. 1451. The wool is fed promiscuously at the back, a large supply being placed in the feed-box or receptacle *a*, which has a grating at the bottom, to permit dust or similar refuse to pass through. At the rear of this box, is an elevator, a toothed apron, the teeth of which are of peculiar construction. These teeth take hold of and carry the material upwards, until it arrives in contact with an oscillating comb, which has a long slow sweep in front of the apron. The function of this comb is to take off the surplus wool from the apron, leaving only an evenly-distributed layer amongst the teeth of the latter. On the descending side of the apron, it is brought into contact with a short stripping-apron, the action of which is much quicker. This is produced with flexible strips of leather, which sweep off the wool from the teeth, and convey it in connection with a hollow or concave shell into a weighing-scale *b*. This scale is composed of two parts, kept together by weights, the whole being suspended on steel knife-edges, and balanced with movable weights, which can be fixed to weigh any desired weight. When the scale has received its proper amount, it liberates a small trigger, which causes a projection to come into contact with the teeth of a revolving disc, connected with an automatic clutch that disengages the driving-belt actuating the toothed apron, and stops the further delivery of material to the scale, which now remains at rest. When the proper moment arrives, the parts of the scale separate, and deposit the wool on the feed-lattice *c* in a loose open condition, well suited for the cards. The scale then closes, and is carried back for more wool, the toothed apron recommencing its revolution, and the process going on as before. In the meantime, the lattice which has received the wool has moved on, and has brought up a clear space on which to receive the next discharge.

1451.

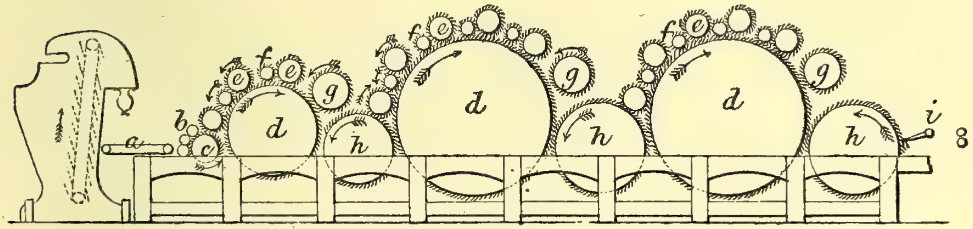


This attachment to the card has met with great favour in America, and has latterly been received with approbation in this country, numerous manufacturers of eminence having adopted it. It takes no more room than the ordinary lattice-table, is complete, perfectly automatic, and requires but little power to drive it. Besides delivering the wool with great regularity, it mixes and opens it, thereby improving its condition for the card. It takes out a considerable portion of the foreign matters the wool may contain, rendering the carding much easier, and preserving the cards. An increased production of 20–30 per cent. is obtained, whilst considerable economy is effected in the matter of wages, one man being able to superintend three sets of three cards to a set. It is so constructed as to seldom get out of repair. The qualities it possesses in combination are that it delivers a uniform quantity over a given space at uniform intervals of time. All these factors can be varied separately or together, so as to produce any modification of the result that may be desired.

The card may be of various widths, and single or double; that is having one or more cylinders. Fig. 1451 shows a single card with the Bramwell feed attachment A on the right, and Tatham's patent balling-machine B on the left. This is another ingenious and comparatively recent invention, the function of which is to take charge of the carded material, and make it ready for the next machine. The wool is coiled or wound upon small wooden bowls or bobbins. The machine has a supply of these bowls *d* placed upon its top, whilst another is held between two discs *e*, shown between the sides of the machine. The wool comes from the doffer of the card in the form of a sliver: a soft untwisted rope, which is then carried through a revolving tube, the action of which imparts more cohesive power to the loose fibres, to enable the sliver to be drawn from the bowl in the next process. When the bowl between the discs is filled, the latter separate and allow it to drop out into a box, and immediately thereafter an empty bowl from those on the top is brought down and placed between the discs, which now close and hold it as before. After the discs have made a few revolutions, in order to attach the sliver to the empty bowl, the sliver hitherto unbroken from the full bowl is automatically severed, and the bowl may then, at the convenience of the attendant, be carried away. This system is highly recommended where the plan of feeding the intermediate card with sliver is in use.

Having described these attachments, the card itself demands notice. As before stated, the cards may have one or more cylinders, or "swifts," as they are usually termed. When two cylinders are used, there are no important differences in the mechanism, the only alteration necessary being that the clothing of the rollers and swift shall be finer in the second than the first. Fig. 1452 illustrates a section of a double wool-carding engine, and its introduction will serve to show the manner of connection between the two parts, and the ordinary method of feeding the machine. They often also comprise a "breast," or a smaller cylinder which is also shown. In the ordinary feed, the wool is placed upon the travelling lattice *a*, and a given weight is as evenly as possible spread upon regular, marked spaces. In this case, the automatic feed attachment is shown also. This lattice carries the wool to the three small feed-rollers *b*, which deliver it to the "licker-in" *c*, which in turn yields it to the rapidly-revolving swift *d*. The series of rollers shown on the periphery of the breast and the large cylinder are termed "workers" *e* and "strippers" *f*. Each worker has its connected stripper. The large rollers *g* are called "fancy rollers," and the larger ones *h* "doffers." The second part is a duplication of the first, possessing in addition merely a doffer comb *i*, which by its rapid oscillation strips the doffer, and delivers the material in the form of sliver to the pressure-rollers, whence it is conveyed by one of several different methods in vogue to the condensor, when no intermediate is in use.

1452.



All these rollers are clothed with appropriate card-clothing, composed of wire teeth bent at given angles, and set in sheets of leather, or of a compound of cotton and indiarubber; these sheets form what is called the card "foundation." Card-clothing is made in the form of sheets, 4–6 in. wide, and of length sufficient to extend across the breadth of the machine. The number and fineness of the staples or teeth vary according to requirement and the position they have to occupy in the machine. These sheets are nailed across the face of the cylinder with great care, so as to present a perfectly even surface, curving only to the periphery of the cylinder, doffers, workers, and fancy, for which they are generally used. "Filleting" is composed of long narrow strips usually $\frac{1}{2}$–$2\frac{1}{2}$ in. wide, and long enough to cover the roller in one piece. The smaller rollers, on which the clothing does not last so long as on the large ones, are generally clothed with filleting; these are the strippers and angle-strippers. One end of the fillet, being made fast to the roller, is then wound helically over its surface, and secured at the other side.

The arrangement of the teeth of the clothing is of importance, in order to secure satisfactory results. In fact, without a proper position and accurate setting, regard being had to the relation of speed each bears to the other, and to the direction of revolution, such a result cannot be had. The old-fashioned way of adjusting the rollers was by sight, but this was seldom satisfactory. A gauge has of late years been introduced, and has come generally into use. By its means, accuracy is obtained and much time is saved.

A brief explanation of the action of the cards may here be given. The "licker-in" takes the wool from the feed-rollers, the card-teeth operating as hooks. As the periphery passes round to the cylinder, the teeth are then in the act of ascending (the bend being thus in the opposite direction), and presenting facilities for being stripped of the wool they have acquired. Here the cylinder, revolving 80–100 times, equal to a surface velocity of 1000–1200 ft. a minute, and its teeth bent upwards, takes the wool from the licker-in, and rapidly carries it forward to the first worker *e*, The teeth of the worker are bent in the opposite way to those of the cylinder; and though its revolution is in the same direction, its surface velocity is so much less that it takes the wool from the cylinder, a sharp carding or combing of the fibres taking place. As the worker carries the wool slowly round, it is relieved of its burden by the more swiftly revolving stripper *f*, whose teeth are bent upwards, and work against the back or smooth side of those of the worker, at the point of contact of their peripheries. The stripper as it carries the wool round presents the smooth side of its cards in turn to those of the cylinders, whose speed again enables it to take possession of the wool, which it then carries forward to the second worker, to which it again yields possession, and the operation just described is again gone through; this is repeated at each succeeding stripper and worker, until all have been passed. The next roller to which the cylinder carries the wool is the "fancy," whose function is quite different from that of the workers or strippers. This revolves at a high velocity in the same direction as the cylinder, yet though their teeth are set opposite to each other, its action is not to strip the cylinder—the actual passage of the teeth being back to back—but to raise the wool to the surface of the cylinder teeth, so that it is easily taken possession of by, or rather is thrown upon the teeth of, the slow-moving doffer, which are arranged with the bend upwards, in order to receive and retain it, until stripped by the first roller of another cylinder's set (as shown in Fig. 1452) or cleared by the doffer-comb at the end of the cylinder's work. The work of the scribbler is now concluded, and, if well performed, the basis of a good yarn is laid.

Usually a set of cards is linked together in working, the product of the scribbler being automatically carried to the "intermediate," and that of the latter to the condensor card. This is done to obviate certain defects of the scribbler, which has a tendency to deliver the wool in an uneven sheet from the last doffer. The purpose of the intermediate feed is to so present the wool to the next machine that their irregularity shall not lead to defective results. There are a considerable number of these "feeds," but the most characteristic are those known as the "Scotch feed," "Marsden and Blamire's feed," and the "ball feed."

In the Scotch feed the wool is doffed from the scribbler doffer by the comb, and delivered upon a narrow travelling apron in the form of a sliver 3–6 in. broad, which passes through a series of rollers, whose object is to compress it and secure its adhesion whilst in transit to the next machine. From these rollers, it ascends to a travelling apron or belt arranged overhead, upon which it is carried to a point over the lattice-feed of the next machine. Descending here, it is given to a travelling carriage, passing between two rollers as it is carried from side to side of the lattice-feed. The carriage lays the sliver obliquely across the feed, the edge of one layer overlapping that of the preceding to nearly half its width, by which means a uniform layer or sheet of material is formed for delivery to the card. This, entering the feed-rollers obliquely as deposited, has its inequalities to a great extent obliterated.

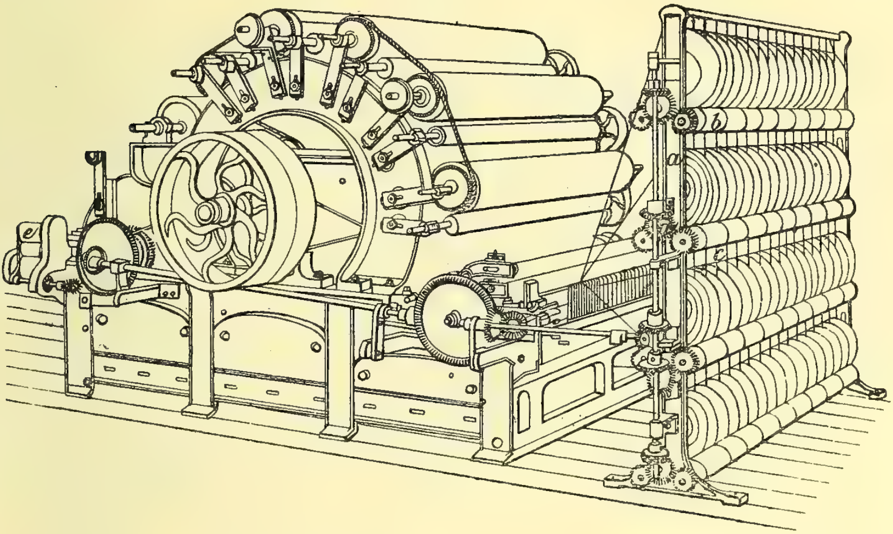
The arrangement known as Marsden and Blamire's feed, though not very different in principle, diverges considerably in its details. As the film of wool is doffed, it is laid upon a travelling lattice, which moves away from the doffer, and delivers the material through several guide-rollers to another lattice, mounted on a carriage underneath the top lattice, and which moves inwards and outwards, that is towards and from the doffer, thus causing the scribbled material to be deposited in layers until a sufficient thickness has been formed. The carriage lattice upon which the wool is thus laid, however, moves in a direction transverse to the upper one and to the direction in which the wool is delivered from the machine. In this manner, the scribbled material is delivered sideways to that in which it has been carded, as in the preceding feed, and passing between a pair of rollers, is received by another, and wound into a lap. When fully formed, this can be removed without stopping the machine.

This feed is very suitable for a low description of work, as it obviates the breakages of sliver that are apt to occur when the preceding form is used. It will be obvious that the fibres of wool in passing through the scribbler have been laid approximately parallel, and are doffed in that condition. The transverse delivery of the lap to the next machine causes the fibres to enter sideways, by which the inequalities of the lap are eliminated. This has also the effect of destroying the parallel arrangement of the fibres, crossing them in different directions, and so aiding in the production of a crossed fibre condensor thread, the best arrangement of the material in a thread for cloth which has to be shrunk or milled in the finishing process; it also assists materially in the production of a full nap upon the fabric, the end of every fibre lying on the surface of the threads. This system of feeding is in most general use where the "set" consists only of the scribbler and condensor.

One or other of the three systems of connecting or feeding the succeeding machines from the scribbler, or modifications of them, will be found everywhere in use. Special circumstances will always decide the adoption of the most suitable.

The cheese-shaped balls of wool from the scribbler, Fig. 1451, are taken to the "intermediate," and to a greater or less number as required are placed in a creel or bank *a* shown in Fig. 1453, an illustration of the intermediate carding-engine. As given, it represents a machine 60 in. wide, with one cylinder, six workers, six strippers, "fancy," and doffer. In the creels, the balls rest on their edges upon two rows of rollers *b*, and are maintained in the vertical position by slight bars *c*. The rollers are made to revolve and unwind the sliver from the balls by means of the bevelled gearing at one end of the creel, as shown in the figure, thus delivering the sliver without strain, which, if permitted to occur in a slight degree, would attenuate it, and thus render the product irregular. The slivers are conducted between a series of vertical pins, to prevent any overriding and uneven distribution as they pass through the feed-rollers, and thence through the series as named above. These, being precisely similar in their functions and details, except in the matter of clothing, which is finer, need not further be noted.

1453.

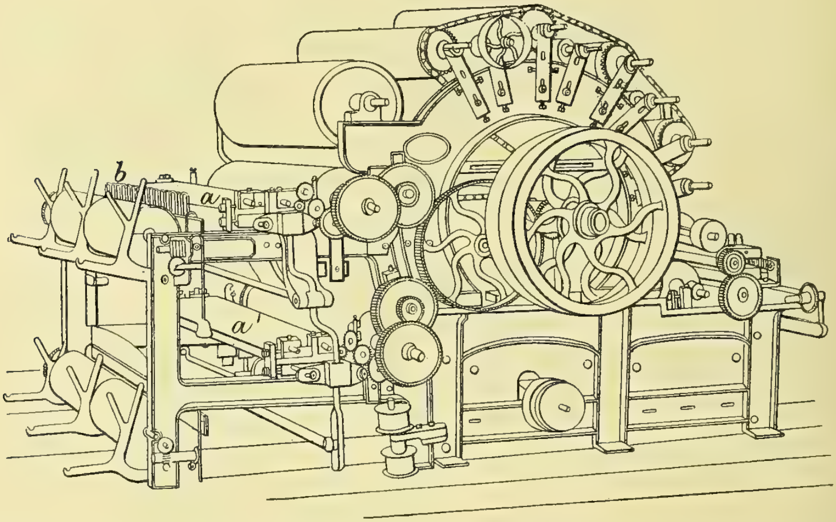


Emerging from the intermediate card, the wool is doffed in the form of a flat sliver, which, by an apparatus, is concentrated or condensed from the width of the machine (in this instance 60 in.) to about 4 in. wide, and which, in its passage from this machine, is compressed between the small rollers *e* seen on the left of Fig. 1453. It is then conveyed by one or other of the feeds, or modifications thereof, to the finisher-card, Fig. 1454, which is similar to the preceding, excepting in the feeding apparatus being different, and more like the Scotch feed previously described. Here the carding is completed. Attached to, and working in combination with it, is the condensing-machine, by which the carded wool is delivered in narrow ribbons from the doffers—one or two, as it may be single or double—and which, passing between the rubbers, are, by a rapid transverse movement of the leathers, rolled or condensed into a coarse round thread. The doffer-cylinder of the condensor-card is modified, by the clothing being divided, so as to form rings separated from each other by given spaces. The effect of this is that the film of wool is doffed by the comb in narrow ribbons or strips, instead of, as in the preceding cases, in one sheet. The machine shown in Fig. 1454 represents the latest make of the double rubber-condensor. After the sliver strips or ribbons leave the doffer, they are conducted between the pairs of leather aprons *a a′*, each pair forming a "rubber." These aprons are stretched each between two rollers, and neatly sewn together, so as to form a travelling apron when the rollers are made to revolve. One of each pair is placed above the other, near to but not quite in contact. Appropriate gearing at the side causes them to revolve, by means of which, the ribbons of wool would be carried forward in that form, did not another movement intervene to prevent it. This is a lateral movement of the leathers in a direction transverse to that of their revolution, each leather moving in this manner in the opposite way to its associate. The effect is to rub the sliver strips into a round thread, as stated, in the same manner as if they had been rubbed between the palms of the hands. The strips of sliver are thus both carried along and rolled as they come from the doffer, this being done without their suffering attenuation. These aprons extend across the machine, and vary in width from 12 to 20 in., according to the work they have to perform. The condensed threads, after they leave the rubber, are conducted through a guide-comb *b* and upon condensor-bobbins placed in the standards to receive them. These when full are removed and are ready for the creel of the mule.

This form of condensor is in general use all over Europe, and, in the opinion of the best practical judges, is the most useful and perfect condensor in existence for all round work. In the American woollen trade, another kind is in use, called the roll-rub condensor; but, as practical writers in the United States admit the superiority of the foregoing, it is not necessary to describe it.

Carding is probably the most important of all the processes of woollen manufacture. Nothing tends so much to success as its proper performance, and nothing so much militates against that result as when it is badly done. The essentials of good carding are numerous, and include a proper arrangement of the machinery; nice adjustment of the parts, especially the rollers; careful clothing; good grinding; flocking; and correct relationships to each other of the speed of the cylinder, workers, strippers, fancy, and doffer. These are matters that call for attention before the commencement of work. During working, there are equally numerous conditions that require examination. Care should be taken not to overload the machinery with wool, which would result in defective work, as the cards would pass it on without sufficient treatment. The cards should never be permitted to fill up either with dirt or wool, as the material in process is thereby apt to be rolled. The technicalities of the treatment of wool and the management of the machinery are so numerous that to enter into detail upon them would extend this article to the compass of a volume.

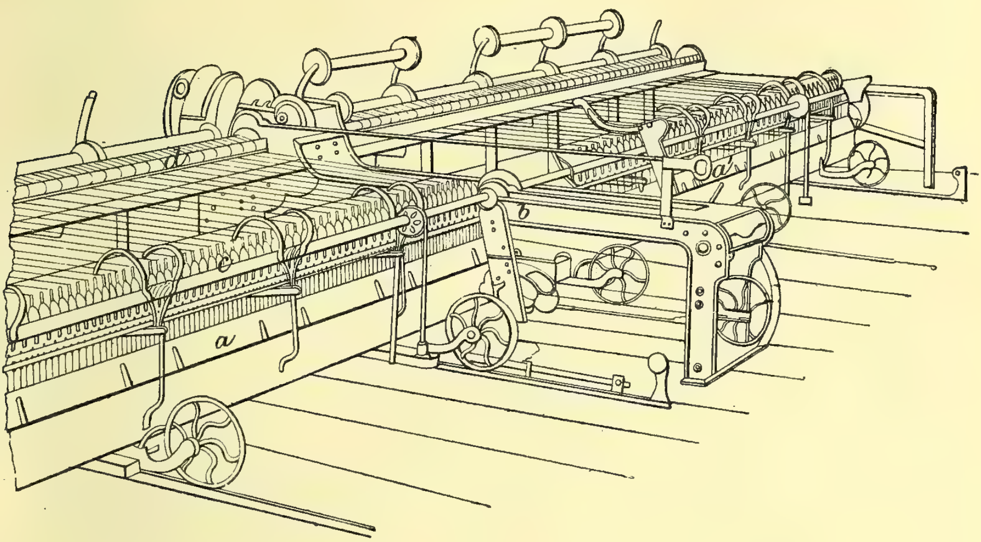
1454.



Spinning.—Woollen yarn is usually spun upon the mule; there are several continuous spinning machines, but though invention has been directed for a long time to the construction of a good continuous spinning-frame, no such machine has yet achieved a commercial success. The mule, as is well known, is an adaptation from the cotton trade, like the carding engine and many other machines in the various sections of the wool manufacture.

The woollen mule (Fig. 1455) is much simpler and has far fewer spindles than the cotton-spinning mule. In general appearance it is much like the other, and consists of two carriages *a a'* mounted on wheels with the headstock *b* placed between them in the middle. Each carriage is fitted with a number of spindles *c*, usually 500–600. The frame consists of the roller-beam and creel carried upon the usual standards. The difference in the nature of the fibre of wool from that of cotton precludes the use of drawing-rollers, as in cotton-spinning. The woollen mule is therefore only furnished with one row of fluted rollers, provided with a corresponding row of top rollers *d*. The condensor-bobbins being supplied to the frame, the threads are drawn off, passed between the rollers, and attached to the spindles. The mule is then ready for commencing work. Simultaneously the spindles begin to slowly revolve, the carriage to draw out from the roller-beam, and the rollers to deliver the condensor-threads. When the carriage has traversed about half its journey outward, the rollers cease to deliver the material. The carriage proceeds on its course, and the spindles continue revolving, by which means the condensor-threads delivered from the rollers are gradually attenuated, until, by the time the carriage has reached the extremity of its traverse, this is completed. The thread, however, as yet is only soft and loose, and must be rendered comparatively firm and strong. In order to accomplish this, the revolution of the spindles is greatly accelerated, and the thread rapidly twisted. This twisting takes up the length of the extended thread, in order to allow for which the carriage is made to move in a few inches as the twisting proceeds. When this is completed, the spindles are automatically arrested, and for two or three turns have their movement reversed to form the "backing-off process," as the unwinding of the several turns of yarn upon the spindle-tops is called. This being performed, and the slack simultaneously taken up by the "fallers," the carriage proceeds inwards, winding the threads upon the cops until the spun portion is all thus disposed of. The process then recommences, and is repeated in all its details, recurring until the set task is accomplished. When the spindles are filled, they are "doffed," that is, cleared, and a new set is begun.

1455.



The yarns thus spun may be either for warp or weft. The former constitutes the longitudinal threads of a woven fabric, and is usually well twisted; the latter forms the transverse or cross threads, and generally contains rather less twine than that intended for warp.

Manufacturing.—The processes up to this point form the first half of those comprised in the term woollen manufacturing, and are termed woollen spinning. The second half, or manufacturing, will require comparatively brief treatment.

The woollen thread as it comes from the mule will be natural, grey, black, or any other colour, according to the component parts of the blend from which it has been spun. When dyed in the loose fibre, wool is termed "wool-dyed"; when in the state of yarn, "yarn-dyed"; and when in the woven fabric, "piece-dyed."

Twisting or Twining.—Woollen yarns are generally used in a twofold form: that is, two threads are twisted together to obtain strength, bulk, and variety of pattern. This twisting process is done upon the mule, which is generally adapted for both spinning and twisting. In combining two threads, care must be taken to twist them in a direction opposite to that in which the individual threads were spun. This is in order to prevent it afterwards running into kinks. The twisting is performed by placing the threads in the creel, bringing them under the rollers, and attaching two threads to each spindle, when the twisting is performed as in the spinning process. To make self-coloured twist only needs the combination of two threads which are alike. To produce fancy yarns, it is necessary to combine different, which may be harmonious or contrasting shades or colours of yarns, and which may also be of different materials: wool, silk, cotton, flax, China-grass, or other fibrous materials. Although twisting is ordinarily performed upon the mule yet it is in process of being superseded. Messrs. Sykes of Huddersfield have introduced into the market a twisting-frame which has been extensively adopted, and is found to give very satisfactory results. In preceding articles (see Rope, pp. 1699–1701; Silk Manufactures, pp. 1751–3) a more recent invention, a doubling-winding, and a twisting-frame, made by Thomas Unsworth of Manchester, has been referred to and illustrated. The employment of these two machines for twisting purposes effects a very large economy when compared with the ordinary method, as is demonstrated by the following figures. At an important manufacturing establishment at Tourcoing in N. France, where these machines have been introduced, a comparison has been instituted, and the following results arrived at:—A 200-spindle machine making on the top or delivery spindle 4500 rev., and front spindle 4500 = 9000 rev. per minute, working 3-fold 42's worsted, produces in a week of 81 hours, 420 *kilo.* of twisted yarn of a very high quality. This is done at a cost in wages of, for winding, 75 *fr.* 60 *c.*; for twisting, 20 *fr.*, total 95 *fr.* 60 *c.* = 22 *c.* per *kilo.*, as against a production in the same mill on a good ordinary system, and a machine containing the same number of spindles, running the same hours and working the same yarns, of 250 *kilo.*, at a cost for winding of 45 *fr.*, for twisting, 40 *fr.*, total 85 *fr.* = 34 *c.* per *kilo.* In the latter system, two girls are required at the twisting-frame, whilst in the former, only one is needed. It is obvious that a regard for economy will compel the adoption of the improved methods now being introduced to the notice of manufacturers.

Designing.—At this stage, the services of the designer are called into requisition. Designing patterns for fancy woollen cloths implies the classing or arranging of the contrasting and harmonizing shades or colours, both of the warp and weft, by the combination of which in a fabric chaste and saleable patterns are produced in the cloths. Many colours may be employed in the warp, which, if crossed by a plain weft, would produce stripes; or an equal, greater, or less number of colours may be used for the weft, when a checked effect would result. By the transposition of these coloured threads in the warping and weaving, an endless variety of plaids and stripes of various dimensions can be produced. Combinations of patterns may also be obtained in great number from the use of two or three colours of warp and weft. As each lot of yarn is twisted according to instructions, a ticket is generally attached, expressing the lot and numbers, the length, and the breadth. The length is stated in "strings" of 10 ft. or 120 in., and the breadth in "porties" of 40 threads each. When the warp is to have stripes in it, one set or complete pattern is usually drawn on the ticket as a guide to the warper and weaver.

Warping.—The warping mill, in which the yarn is combined into a warp, is a large vertical reel of about 20 ft. in circumference, or two standard "strings." The hand warping-mill is only half the size of the preceding, and in small manufactories is yet in use. The length of the warp is varied according to requirement. The best way of warping is to arrange the threads in even numbers, say 40, 44, 48, 52, 56, or 60 threads in a "bunch" or "gang," and to divide them into four equal parts, that is 10, 11, 12, 13, 14, 15, on the under leash-pins. The number of bobbins or cops required should be set in the creel, and the threads be conducted through the eyelets of the guide-pins, one half above the other, each thread thus being alternated, which will leave a space between them. The warper then collects and ties the whole bunch of threads together, inserts his thumb into the open space, and crosses every thread upon the top pins, so as to form the leash. The reel is next set in motion, which is continued until the length of the warp has been reeled, when the leash is again taken on the pins, and this process is repeated a sufficient number of times until the proper quantity of threads is obtained to form the width of the warp or chain. When this is completed, the end is securely tied to prevent entanglement, the leashes are secured with bands of yarn, and the warp is well marked at each "string" for the guidance of the weavers. To each warp is also supplied a number of "listing" threads, of stronger yarn than that forming the bulk, from which the lists or selvedges of the cloth are woven. About 100–120 of these threads are required to form the two selvedges of a broad cloth, and about half that quantity for a narrow width fabric. The warp is usually made in the form of a chain in the woollen trade. This is simply a peculiar arrangement of the warp.

Sizing.—The nature of the raw material, and the method of manufacture of the woollen thread in which the fibres are crossed in various directions, render the process of sizing a necessity. The purpose of sizing is to lay smoothly in a parallel direction all the protruding fibres on the surface of the yarn, so as to diminish the friction; and to solidify the threads and increase the strength, to fit the warp for the reception of the weft, and to enable it to withstand the strain occurring when the latter is driven home by the "slay" or batten. The process is of considerable importance, as the production of good cloth requires that it shall be well and evenly performed. It is also highly necessary to the weaver, as when properly executed, her labour is much less; and, weaving being usually piece-work, the production is greater, and her earnings larger. The chain or warp is generally immersed in a vessel containing the sizing preparation, and when thoroughly saturated it is squeezed out, either by hand or by a wringing-machine constructed for the purpose. The "size" is usually some strong glutinous matter, sufficiently firm to lay down the somewhat refractory fibres of the wool. A good size is composed of prepared rabbit skins dissolved by boiling in water for about three hours. After the warp has been properly sized, it should be thoroughly dried, which is accomplished either by laying it at length, or winding it on a drying-machine to prevent injurious consequences.

Beaming.—Beaming is the winding of the warp upon the loom-beam. It is accomplished by the aid of a simple machine called the "beaming-frame." The first care of the beamer is to lay or distribute the threads of the warp evenly in the ravel, a coarsely-set reed or frame, the upper part of which is removable, in order to permit of the warp threads being placed between the vertical pins or teeth, which having been done, the top or cap is secured. A rod, which fits into a slot or groove extending the length of the flanged beam, is next inserted into the end of the warp. The warp is then wound evenly and tightly upon the beam. Should the winding not be perfectly level, defects would be caused in the cloth, owing to the different tensions at which the warp threads would be woven, some being slack, and others tight, which would afterwards result in uneven milling, and other defects in the finishing processes. When the warp has all passed upon the beam, two rods are inserted in the leash formed by the top pins of the warping-frame, which, being tied together, secure the perfect alternation of the threads.

Drawing-in and Twisting.—The warp is now ready for attaching to the healds or harness. In the case of a new set of healds being required, the beam is suspended in a frame, or by means of strong cords, with the warp end falling a short distance down. The "healder" or "drawer-in" takes his seat in front of the healds, and a child assistant called a "reacher" sits at the back. The former opens the healds in succession, and puts through the eyelets a small hook constructed for the purpose, called a "heald-" or "reed-hook," into the eyelet of which the reacher inserts one or two threads, as the hook may be single or double, which are then drawn through to the front by the drawer-in. In this manner he proceeds until all the warp-threads are thus entered, and the drawing-in or healding is complete. Simultaneously with this operation the threads are also drawn into or through the reed by the drawer-in. One thread is drawn through the eyelet of each heald, and two through each space between the dents of the reed, when the design is to make a plain fabric; three, four, five, or six threads may be drawn through each reed space for various sorts of twills and fancy cloths. The warp is now ready for the loom, which introduces the last principal operation, subsequent ones being subsidiary to this, and variable according to the nature and purposes for which the fabric is intended.

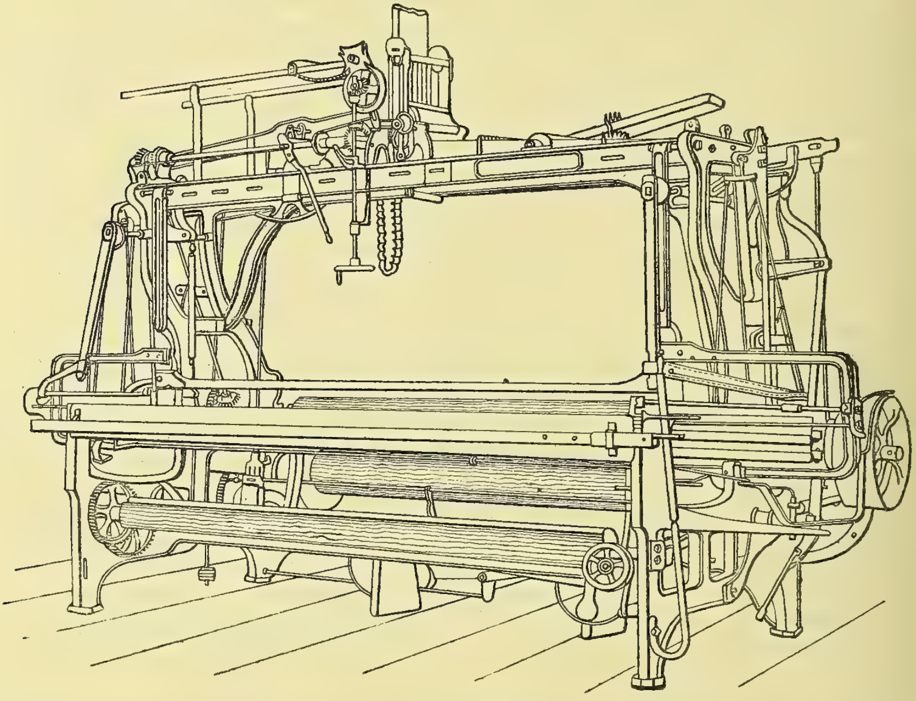
Weaving.—Weaving is a very ancient art, and in its origin consisted probably of simply interlacing reeds with each other in order to form mats on which the people of Eastern countries, with whom the art is supposed to have originated, might recline. These reed textures are made to this day in the countries referred to; and, amongst the Chinese, very largely, as may be inferred from mats being found amongst the articles of export to this country. From this simple process, the development of the art was extremely slow through thousands of years until the early part of the 18th century, when Kay, of Bury, in Lancashire, inaugurated the present grand epoch of mechanical invention by devising a plan whereby a weaver could throw the shuttle backward and forward across the loom by one hand, and which also enabled him alone to weave the broadest cloths; whereas, by the plan then in vogue, two weavers were required. Improvements followed each other in rapid succession, until by Dr. Cartwright's happy thought and mechanical skill, the automatic loom was designed and invented. This was about 1789, since which time the progress in developing and perfecting the loom has been simply wonderful, until now there seems little left to accomplish, unless it be to dispense with the presence of a superintendent altogether.

The capability of the loom as turned out of our first-class machine shops is something at which surprise may be justly expressed. It is questionable whether in the whole range of mechanism anything more wonderful can be found. Being supplied with warp and weft, properly adjusted, and connected with motive power, the loom with only small supervision will fabricate textures varying from the plainest calico to those of the most gorgeous beauty. The warp is opened, the shuttle with its cargo of filling is thrown between, leaving a trail of thread behind, which is driven home by the advancing lathe or slay, the latter immediately retiring to make way for the shuttle again, when the operation is repeated. This goes on not at a creeping pace, but with almost lightning rapidity, 200–400 transverse threads being put into the web per minute. At the same time, the cloth is being automatically taken up in front of the loom, and the warp delivered at the back with the most perfect regularity, ensuring thorough uniformity in the structure of the fabric. Plain fabrics, alike on both sides, twilled fabrics, plain on one side, or twilled on both, or patterned in various ways, can be produced with equal facility. Coming to more intricate textures, striped, chequered, and numerously variegated designs can be obtained as desired, by the aid of the many attachments invented for extending the capacity of the loom, either in plain, self-coloured, or variegated forms. With the Jacquard machine as an adjunct, the power of the loom in the variation of pattern becomes practically illimitable.

The Jacquard apparatus has been modified and adapted to many purposes. One of limited range, called the "Dobby," is used for the production of small patterns and of figured borders in cloths having a plain centre. Others are taken away from shedding purposes altogether, and adapted to work both rising and revolving systems of shuttle-boxes, by which means, from one to any number of picks can be obtained from one shuttle, and the whole number alternated according to desire.

These remarks will obviate the necessity of making detailed statements concerning the mechanism of intricate looms which the general reader would find it difficult to follow, and which to the expert are already well known. Fig. 1456 is a perspective view from the front of the well-known Dobcross woollen loom, so called from the town in which it is made. The firm from which this emanates, Hutchinson, Hollingworth, & Co., is of considerable repute in the woollen districts, and the loom represented is high in favour. A peculiarity is that the slay or lathe is suspended from the top of the loom, according to the old plan, but which, in some cases, it is deemed desirable to retain, even though regarded as antiquated. The Jacquard or Dobby with which it is mounted, is adapted to work from 3–34 shafts or heddle-leaves, and is on the double-lift principle: that is, its action is of the positive kind in both lifting and pulling downwards the heald-shafts in order to make a shed for the passage of the shuttle. In the single-lift, the arrangement is confined to lifting the healds, their depression or return being obtained by the action of spiral springs or weights underneath the loom. The unreliability of this plan is well known to practical men. Thus, when working, the healds are always being raised or depressed by positive means. This loom is constructed with three, four, or five boxes on the rising plan: that is, each box containing its shuttle is brought on a plane parallel with the shuttle-race, according to requirement, by being elevated or depressed to the position, according as it may have stood at the moment. Every change of position in the boxes requires the whole number to be moved up or down, as needed. In doing this, a great deal of inertia had repeatedly to be overcome in elevating the boxes, whilst their descent entailed a considerable shock, owing to the distance through which they had to fall, and the influence of gravitation. The former circumstance absorbed a great deal of motive power, whilst the latter entailed a heavy wear and tear. Both these defects have to a great extent been obviated by the introduction of a plan of balancing the boxes, by which they can be elevated or lowered with greatly increased facility, and which renders them much easier to control. A simple method of connecting the shuttle-box motion with that which controls the pattern motion, so as to ensure harmonious action, was for a long time a great desideratum. In patterned goods, it will be obvious that one thread less than the required number in the weft will cause a serious blemish in the cloth. This may easily occur through the breakage of the weft whilst the shuttle is crossing the shed; and when this happens at the moment when a change is about to take place, the loom may continue working, the automatic stopping motion failing to detect the lapse. In this case, it is compulsory to rely upon the carefulness of the attendant weaver, whose duty it is instantly to stop the loom, pull out the picks that have subsequently been put in, and reset the loom to commence correctly at the place where the defect occurred. To do this has not been an easy matter for the weaver, the box and the pattern motion having to be reversed, which, in the case of a cumbrous machine —as a large power-loom proves to be when it has to be operated by human power, and that generally a female—has often proved almost insuperable. In the best-arranged plan, much delay has

1456.



generally occurred, which in itself is an economic evil, greatly lessening the production. In the loom represented here, a plan is incorporated of controlling the picking motion and that for lifting and lowering the boxes, both of which are controlled by the pattern chain; so that whatever changes may be required to be made owing to broken threads, unweaving defective portions, or other causes, all the parts can be readjusted correctly with quickness and facility. In woollen yarn, there frequently occur variations in the thickness sufficiently great to cause serious defects in the cloth, in the event of the same number of threads being put into, say one inch of warp, when during the next inch a finer weft might happen to follow. This defect is obviated by the provision of an automatic regulation, by which the delivery of the warp is retarded or expedited according to the varying requirement of the yarn. Approximately even cloth thus results, which would not be the case were the delivery of warp constant and unvarying.

Such is the woollen loom as made at present. There are numerous other makers, whose machines are equally deserving attention with the one illustrated, and before deciding, an intending purchaser should carefully examine those in the market, and select the one that will best suit his requirements.

In weaving plain cloth, four leaves of healds are usually employed, though only two are necessary. These are arranged to work in pairs, as follows: 1–2, 3–4. The first two ascend and descend together, and similarly the second pair, each pair being linked in the treading-motion. If the threads of the warp passed in the same order through the healds, the consequence would be that the threads would be placed in pairs side by side in the fabric. But this is not the case: the threads being passed through the healds in the following order, 1–3, 2–4, the first two of these going together in the space formed by two dents of the reed, and the second pair in the next space. This order prevails across the width, until, at the sides, where more strength is required, the threads are doubled or run two together through one heald, and four in the reed space. Sometimes threads of other materials are used for this purpose. By this means, the weft thread is made to pass through the warp shed in such a manner that it shall be placed in an alternate manner under and over the threads of the warp. This constitutes a plain cloth.

The first departure or variation from the plain fabric is to the 3-leaved twill, in which every third thread of the warp is sunk in succession, the picks of weft passing *over* one and *under* two threads of the warp. This texture gives a diagonal pattern to the cloth on one side, the reverse being plain. In this case, the heald-leaves are actuated independently of each other, and not conjointly in pairs as above. This texture is termed the "prunel," or "blanket," and sometimes the "llama" twill. The 4-leaved twill sends the weft *under* three threads in succession and *over* the fourth, by which the latter is interwoven. The name of this is the "Cassimere" or "Kersey" twill. There are other variations of the 4-leaved twills, in one of which the weft passes under two and over two, making both sides alike, except that on the face or front the diagonal line, which forms the pattern, runs to the right, and that on the back or reverse to the left. Others are variations on this basis. The 5-leaved twill flushes four-fifths of the weft on the back, and four-fifths of the warp on the face. The number of leaves may be increased up to 16 or even more, but when they exceed 5, they are generally employed in woollen fabrics in conjunction with the jacquard attachment for the production of a variety of fancy patterns.

In the woollen manufacturing districts, weavers do not usually attend to more than one loom, as it is highly necessary for them to bestow upon their work the most careful attention, in order to prevent defects, the occurrence of which would damage the cloth in the estimation of the purchaser very considerably, and in some cases render it unmerchantable. These defects are technically called "broken picks," "doubles," "thick threads," "raws," "gerners," "flakes," "twists," and many others, which it is not necessary to stop to define. Warp threads occasionally break, and if the weaving is continued without these being repaired, a defect is caused. In piecing them, care must be taken to join them by means of a short length of thread, called a "thrum" or "beeting," of the same quality and colour as the broken one. These thrums are provided for the purpose.

To secure a full production and a proper quality of cloth, the overlooker, or "tuner," as he is called, should be careful to see that the parts of the loom are properly adjusted to each other, so that all will work together in harmony. Otherwise delays, fractures of yarn, and defects will be numerous, the quantity and quality of the production will suffer, and ultimately the reputation of the manufacturer will be injured.

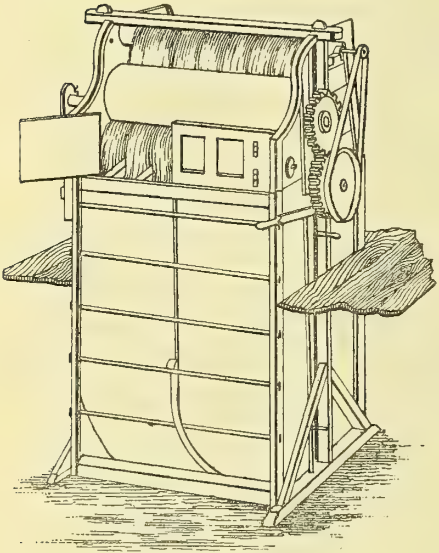
The actual production of cloth from a loom engaged in weaving woollen fabrics will be about 20 per cent. less than would be supposed from a calculation based on the assumption that the loom was continuously working during the hours allowed by law. The time thus lost is absorbed in changing shuttles: that is, supplying full for exhausted ones; piecing warp threads, and other necessary operations.

In weaving heavy close fabrics, it is best to saturate the weft yarns in soft water, and then place them in a hydro-extractor for a short time, so that the superfluous water may be taken out. This will greatly facilitate the weaving.

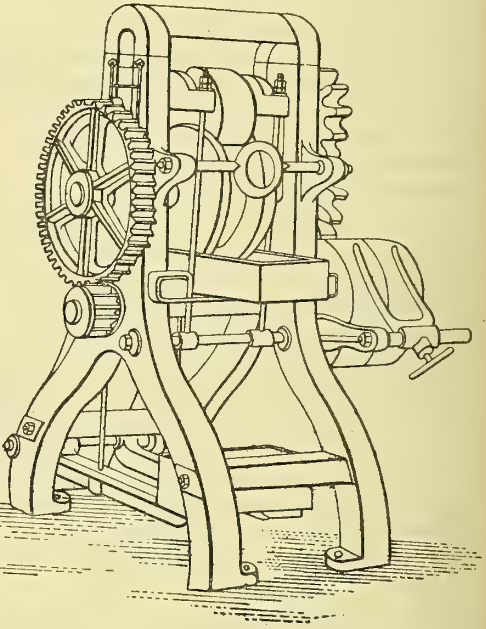
Knotting, Scouring, and Burling.—When the weaving is completed, the piece of cloth is taken out of the loom, and should, if it has been wet-woven, be well dried, properly lettered, and numbered, in order to preserve its identity through subsequent operations. Then it should be carefully examined, by being drawn slowly over a sloping board or table, in front of a northern light or aspect, and all knots and defects of weaving be removed or otherwise repaired.

The cloth should now be well scoured and washed, so as to cleanse it thoroughly from oil, " size," and other extraneous matter. A new washing-machine has recently been introduced, and is shown in Fig. 1457. The cloth is next to be thoroughly dried and slightly brushed, after which it ought to be again pulled over a sloping table, and have all the broken burrs, kemps or hairs, shives, motes, and other impurities removed. This process is called " burling." There are several plans of drying both yarns and cloth, of which the wringing-machine may be mentioned as applying to yarn, and the squeezing-machine (Fig. 1458), almost similar to the fulling-mill, for woven fabrics; but both these machines are objectionable, and have to a great extent been superseded by hydro-extractors, as shown in Fig. 357, p. 496.

1457.



1458

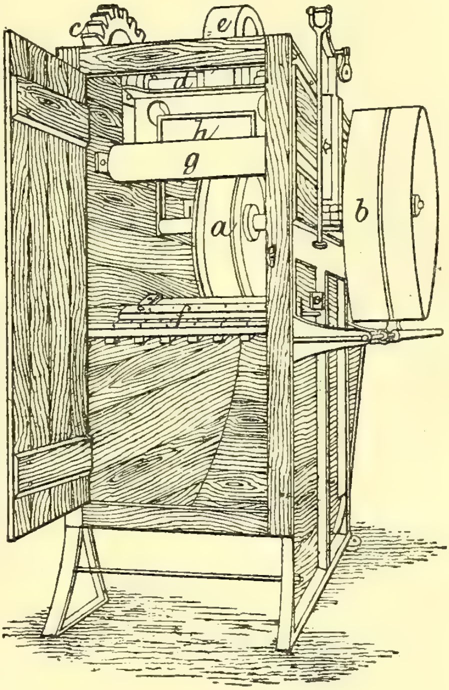


Milling or Fulling.—After leaving the burler, the cloth is ready for the fulling process. The first step is to sprinkle it with boiled or liquid soap, after which it is folded up by the lists or edges into a pile, and placed in the hollow receptacle of the fulling stocks. Here it is milled or hammered for two or three days, or until the fibres of wool become so interlinked in each other as to hide the warp and weft threads. During this process, the cloth is taken out of the mill five or six times, in order to have more liquid soap applied, so as to facilitate the milling process in every direction. This is the method of procedure when the ordinary fulling-stocks are used.

Of late years, however, an improvement has been introduced in the shape of the fulling-mill. This is to serve the same purpose, and is regarded as superior in many respects and for many purposes. Fig. 1459 is an illustration of this machine in its most improved form. The construction is quite simple, being composed of a shaft carrying a flanged roller *a* in the centre of its length, driving-pulleys *b* at one extremity, and gearing *c* at the other, from which a second shaft *d* placed over the first receives its motive power. This second shaft has also a roller *e*, which differs from the first in having no flanges, being arranged to work between those of the first-named. A slotted guide-board *f*, a carrier-roller *g*, and a contracting-tube *h* complete the mechanism, the whole, except the gearing and pulleys, being enclosed. The fulling-mill shown in Fig. 1459 differs from those commonly in use, in being larger in most of its details, having the rollers of greater diameter and the flanges deeper. The guide-board can be made with a slot or two more, and is also fitted with an improved stop motion, consisting of friction-plates that both start and stop the machine in less time than ordinary. The latter is of considerable importance, as, by its prompt action, damage to the fabrics in process of milling is often prevented when entanglement takes place.

The process of fulling with these mills is to soap the cloths as before, place the pieces in the mill, passing the ends through the grooves of the guide-board, over the carrier-roller, through the tube, and between the groove of the flanged roller, in which it is subjected to compression by the action of the top roller pressing upon it. This is continuously repeated until the cloth has been sufficiently shrunk or fulled, when it is replaced by another lot. Tested in work alongside the older form of the fulling mill, it has been found to do much more work, and of a better quality, the same cloth selling for fully 3*d.* a yd. more than when finished in the old machine.

1459.



Whichever instruments are used, the cloth should be milled according to the breadth required. Narrow cloths are milled down to 28 or 27 in. in width, whilst broad widths are reduced from 70 in. to below 60 in., varying anywhere down to 50 in. according to requirement. There are a large variety of fancy woollens that are only subjected to comparatively little milling, or about 10 hours, one-fifth or one-sixth part of this time being occupied in examination of and soaping the cloth. That constitutes "half-milling." Single-milled cloth requires subjecting to the treatment for 12–20 hours; double-milled, 24–40 hours; and treble-milled, 48–60 hours; all inclusive of the time required for examination and further supplies of the milling liquid or soap.

Finishing Processes.—Woollen cloths as they come from the loom are far from being a merchantable article in the ordinary acceptation of the term. The processes to go through before the soft, lustrous, and beautiful finish of the fabrics with which we are familiar is obtained are numerous and almost as important as those that have been already described. They consist of the following: fulling; tentering; 1st raising; 1st cropping or cutting; 2nd raising; 2nd cutting; pressing; steam boiling, &c.; 3rd raising; 3rd cutting; burling and fine drawing; brushing and steaming; 2nd pressing; steaming.

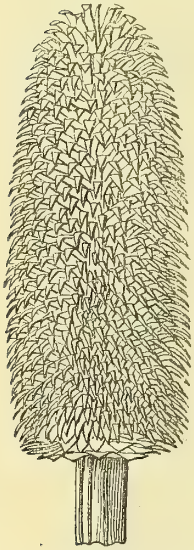
At this point, it will be well to summarize the requisites of a good cloth, or rather the conditions necessary to produce one. First, good sorting of the wool, which gives an even thread and prevents waste; thorough cleansing, essential to the production of good colours, and satisfactory working in every stage. After this, the wool should be well dyed, teazed, scribbled, carded, and slubbed, and carefully spun and woven. The preparatory processes before milling should be properly gone through, the milling well executed, and the fabrics afterwards thoroughly washed in order to remove all traces of grease, oil, or soap that may remain. The details of all these processes require attending to carefully and conscientiously. Any negligence is sure to result in blemishes, and these cannot be eliminated or rendered permanently invisible in the after stages. It takes much more trouble and labour to hide a defect than to keep it out.

After milling and scouring or washing, the cloth should be "cuttled," or folded up closely and laid on the shed floor for a few days. This improves the condition. When it has to remain in the "balk" state, or have its progress arrested some time at this stage, it should be straightened on the tenter-frame and dried, but care must be exercised in seeing that it is not overstretched, either in width or length.

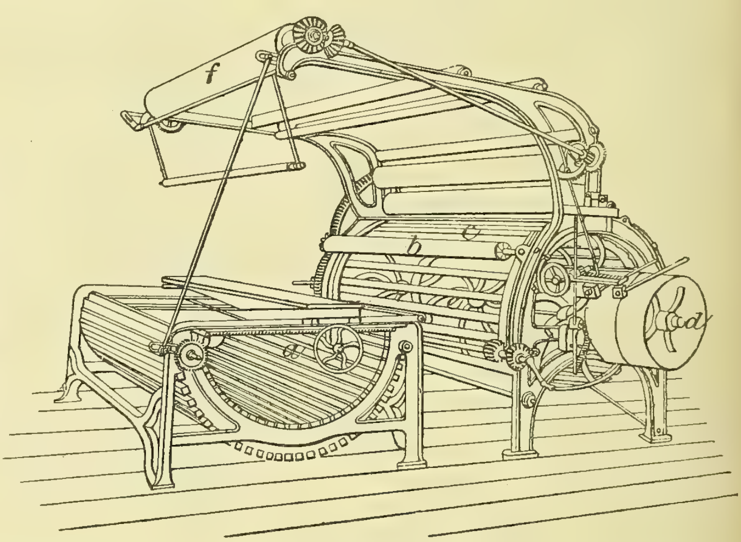
First raising of the nap.—Woollen fabrics rarely show the interlacing of the threads so visible in most other textures. These are effectually hidden by milling in the first instance, and subsequently by the raising of the nap. "Raising" is an interesting process, and consists of scratching up the surface fibres of the wool upon the face or front of the cloth. Formerly it was done by hand, the fabric being thrown over a frame, in the front of which stood the workman with his hand teazle-frame, with which he scratched the surface whilst a companion on the opposite side raised that portion. This process was a very laborious one, and has to a great extent been superseded by the introduction of the "raising-gig."

The teazle, Fig. 1460, is the ripe burr or head of a thistle-like plant called *Dipsacus fullorum*, which is cultivated in several parts of this country (Wiltshire, Essex, Yorkshire), and in many parts of France. Those of Yorkshire are most highly esteemed, and command the highest price. As will be seen from the illustration, the head is cone-shaped and formed of or covered by a great number of hooked points, all curved in one direction downward. These hooks are strong but pliable, slightly elastic, and very smooth, rendering the heads highly suitable for employment in this process. The teazles are cut from the plant with a stem 2–3 in. long, and inserted in an oblong frame called the teazle-rod, with the hooks pointing towards the base, and two teazles in height. When hand-raising is the system employed, these frames are small, such as can be easily wielded by hand, and are furnished with a handle. For the "raising-gig," Fig. 1461, as the teazling machine is called, the frame is about 4 in. in width, and of a length to extend across the gig-cylinder.

1460.

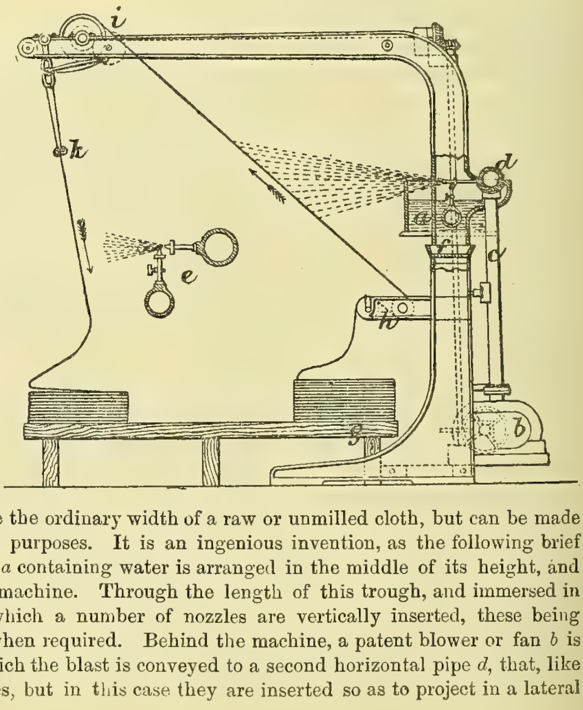


1461.



After the cloth has been evenly stretched and dried in the tentering-frame, it should be thoroughly wetted on the face or front side with soft clear water, and then folded and left to lie in that state for a day or two. This damping is now performed very efficiently by mechanical means. Fig. 1462 represents a "dewing-machine" used for this purpose, which is of recent introduction. It is constructed to take the ordinary width of a raw or unmilled cloth, but can be made wider or narrower to suit special purposes. It is an ingenious invention, as the following brief description will show. A cistern *a* containing water is arranged in the middle of its height, and extends across the breadth of the machine. Through the length of this trough, and immersed in the water, is laid a pipe, into which a number of nozzles are vertically inserted, these being supplied with taps to close them when required. Behind the machine, a patent blower or fan *b* is arranged with a wind-pipe, up which the blast is conveyed to a second horizontal pipe *d*, that, like the former, is supplied with nozzles, but in this case they are inserted so as to project in a lateral

1462.



direction to the tip of the water nozzles. The arrangement is clearly shown in the enlarged view of these parts given at *e*. At *f* is a trough in which the waste water is received.

In working, the piece of cloth to be dewed is placed on the platform at *g*; the end is passed over the first and under the second of the pair of rollers shown at *h*. It then ascends in an inclined direction to the head of the machine at *i*, receiving the spray in its passage. The operation of the fan sends a strong blast from the air-nozzle across the top of the water-nozzle, which causes a vacuum therein, leading the water to ascend to the top, when it is blown away in fine spray against the surface of the cloth as it travels upwards to the head, and, descending therefrom between the rollers *k*, is plated by their oscillatory action upon the opposite end of the platform from which it started. By means of this machine, 15–20 ends of cloth can be damped per hour. A damper enables it to be set to throw any quantity of water from $\frac{1}{4}$–6 lb. upon each piece or end.

After the cloth has been properly conditioned by the ordinary damping or dewing process, it is conveyed to the raising-gig, Fig. 1461. This machine is usually constructed about 65 in. in width on the teazle, but can be made much wider if required. It is shown in the illustration with recent improvements, such as the revolving turntable scray *a*, and expanding breast-roller *b*. The chief part of it is the teazle-cylinder *c*, mounted upon the shaft *d*, which is furnished with driving-pulleys. The cylinder is constructed with 16 oblong spaces *e* around its periphery, for the reception of the oblong frames called "rods," into which the teazles are inserted, fixed by means of their stems; one side of the rod is composed of two parallel bars, having a small space between them for the admission of the stems. The rods are also strengthened by cross-pieces, so that, when inserted, the teazles are firmly held in place. The other rollers shown are for the purpose of securing the uniform tension of the cloth, and bringing the surface to be raised evenly against the revolving cylinder. The revolving scray *a* and the roller *f* with its oscillating arms are attachments whose function is to facilitate the revolution of the piece when the ends are joined together and it has become an endless web. The cylinder is usually run at about 150 rev. a minute.

In operation, the piece of cloth is slowly drawn through the machine in a direction opposite to that in which the cylinder is revolving. This is continued until the ends of all the loose fibres have been brought to the surface of the fabric, when the piece is removed, and again washed off and dried, as a preliminary to the first cropping or shearing process.

When the cloth is laid in the machine so that the cylinder revolves in a direction parallel with the warp or longitudinal threads of the fabric, the action of the teazles will be most effective upon the weft or transverse threads, which they will operate upon at right angles. It becomes questionable, therefore, whether the action of the raising-gig is as effectual as the hand process, and, at the same time, not more injurious to the durability of the fabric. It would appear that the successive operations of putting the latter through the raising-gig must greatly impoverish the weft threads, from the beginning the weakest portion of the cloth. On the contrary, the cross-raising of the hand process brings up the fibre from the warp threads equally as well as those of the weft. This difficulty is, however, almost obviated by a plan of passing the cloth over the cylinders in different directions.

After working some time, the teazle-hooks fill with wool, or "flocks," as the fibres drawn out of the cloth are technically called, which impede their operation. The "rods" are then taken out, and the flocks are cleared out by children, the rods being replaced by another set in order to prevent the stoppage of the machine. Contact of the teazle-points with the damp cloth also impairs their efficiency, and renders it necessary to remove them occasionally for the purpose of drying.

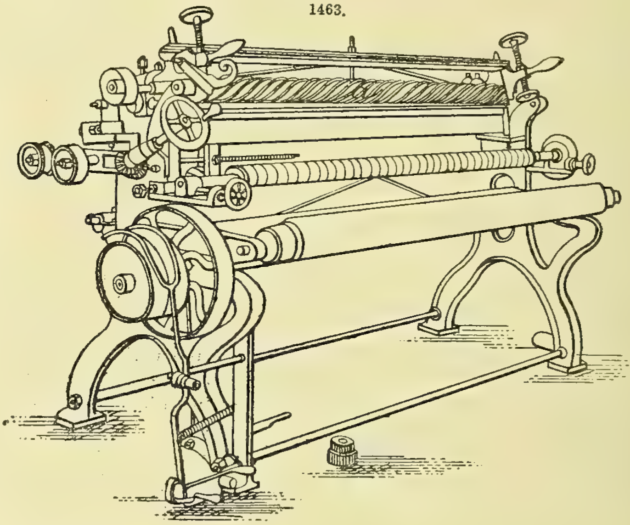
All attempts to substitute metallic cards for teazles have only been partially successful, and as yet there is no likelihood of their superseding the natural article.

Cropping or Shearing.—After the cloth has been sufficiently long in the gig, it is with a little preliminary treatment of brushing next submitted to the operation of cropping. "Cropping" is the cutting of the raised nap (obtained on the surface by the last process) to a uniform level. Formerly it was done entirely by hand, but 60 or 70 years ago a shearing-machine was invented and introduced, after great resistance from the croppers. It has subsequently been much improved, so that it may ultimately be regarded as having quite displaced the hand process. Fig. 1463 is an illustration of the machine in its present state of development, as constructed in this country. It will be understood that there are many modifications of and various forms of it, though the radical principles of each are the same. The essential parts of the machine are the metallic cylinder *a*, into which, and passing helically around it, are inserted a number of steel blades; a straight piece of steel, called a "ledger-blade," fixed across the machine in close proximity to the "spirals," the revolution of the latter in conjunction with the straight blade forming cutting edges; an arrangement of rollers by which the cloth is brought against the cutting blades; and pile or setting-up rollers to raise the nap into the best position for the action of the cutting blades. In working, the long nap is brought against the ledger-blade, in which position the revolving cylinder cuts it down to the desired length. The cloth is passed two or three times lightly through, in order to secure uniform cutting.

The various parts of the machine require to be accurately adjusted, in order to perform its function properly. It is therefore usually made with compensating bearings, in order that, if unequal wear should take place, no defect in its working would result. This arrangement is applied to all the acting parts.

At the second raising, the cloth is damped and conditioned as before, and well raised, after which it is again tentered and dried as a preliminary to the second shearing.

1463.

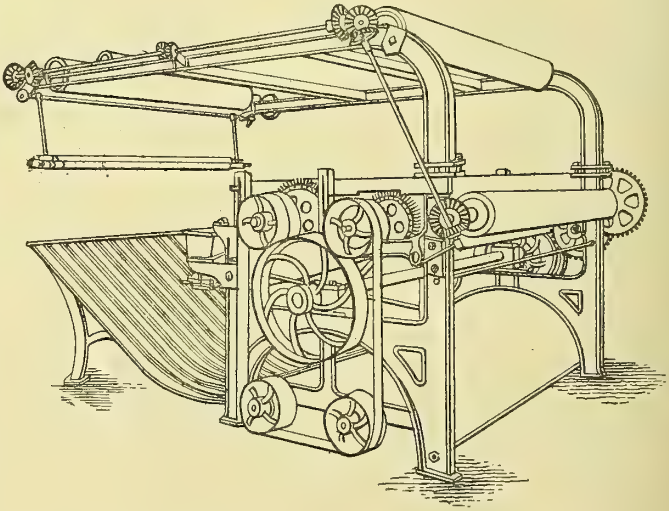


This shearing is like the first, only requiring more care and a nicer adjustment of the piling-brushes and the cutting blades. The cloth must be gone over several times, and nicely cut each time.

After this, the cloth is generally submitted to a good brushing and steaming process, performed by a machine termed the "brushing- and steaming-mill." These mills are made either double or single, and with one or two brushes. Fig. 1464 represents a double brushing- and steaming-mill, with two brushes, one of 12 and one of 13 lags, and steaming apparatus having also a top and sloping scray.

When the brushing and steaming is concluded, the cloth is ready for the first pressing. For this purpose, it is folded into regular lengths, glazed paper being introduced between the folds to prevent the faces of the cloth coming into contact with each other. Heated plates of iron, made hot in a steam-chest or oven (Fig. 1465), wherein steam is used at 30-lb. pressure, are then alternated with each end or piece, and the whole is subjected to severe pressure in a hydraulic press. When the cloth is removed, it is refolded in such a manner as to bring the creases of the previous folding opposite the flat faces of the press papers, by which arrangement they are removed at the second pressing.

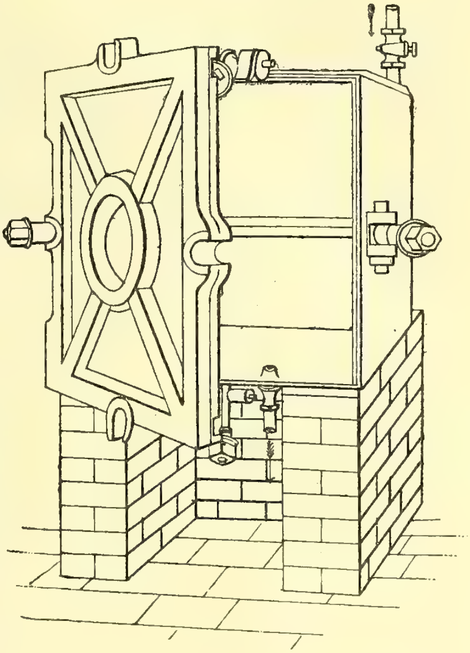
1464.



Steam Boiling.—This succeeds the first operation of pressing, and has for its purpose the production of a permanent lustre on the face of the cloth. The cloth is wound tightly and evenly on round wooden or copper rollers, which have either a plain surface or are perforated with holes, the whole being covered with boiling-wrappers to prevent damage. Permanent and well-dried colours ought to be steam-boiled in a cistern full of water for about eight hours; then taken out and left to cool until the following morning, when the cloth should be wound from the first upon a second roller, by which process the part that was at the bottom before will be brought on the top. It should then be submitted to a second boiling for seven or eight hours. This ought to be repeated if necessary. Mixed shades and common colours should not be boiled or heated to a higher temperature than experience has shown they will bear without injury, which will be found to range between 49° and 82° (120°–180° F.); but they may be dry-steamed considerably higher in a box without water.

Several varieties of cloth manufactured from undyed wool, and intended for piece-dyeing are now at the stage of readiness for that operation. This includes the woaded or light blues, and several other colours. In piece-dyeing, it is requisite that the cloth should be kept well open and the reel constantly turned from the time the cloth is placed in the dye-bath until it is taken out again. If these details are neglected, the result will be a spotted and unevenly dyed cloth.

1465.



After the boiling and pressing has continued sufficiently long to fix the lustre of the cloth, it should be again put through the raising-gig, either in a wet state as before, or with steam applied to the face of the piece on the top of the gig, after which it should again be well washed with cold water, tentered, and dried. It is now sometimes "dry-beaten," or put through the raising-gig in a dry state, in order to loosen the nap for the last cutting process.

In the third and last cutting, especial care is taken that it shall be cut both very light and fine until the nap is reduced to the shortness required. After this, it is brushed on the dry brushing-mill, as a preliminary to the last burling and fine drawing.

Sometimes, instead of the last burling process, the web is inked with black or coloured inks. A machine has been invented to accomplish this process, and is meeting with increasing favour, especially in the case where cotton burls are numerous and require covering. It is adapted for any class of goods, the feeder of the inking-roller being regulated by means of a screw to take up more or less ink as required. After passing through the inking-machine, the fabric ought to be put once or twice through the brushing-mill without steam, and subsequently once with steam, which will greatly improve its appearance.

If burling is preferred, this should be carefully performed, all defects or holes being well drawn up by the fine drawer or mender, after which the lists should be wet and pressed with a hot iron to impart a smart finish.

Brushing and steaming on the steam-brushing mill now succeeds as a preparation for the second hot pressing.

This is a repetition of the previous pressing process, the cloth being again placed between heated press-plates, and subjected to pressure for 5–10 hours, after which it should be refolded and pressed again for a similar length of time.

If, at any of the preceding stages, satisfactory results are not obtained, the process should be repeated.

After having been well pressed, the finishing touch is now given by the cloth being polished with a moderate pressure of steam on the steaming apparatus or mill, which leaves the article in a merchantable state, only requiring making up for delivery.

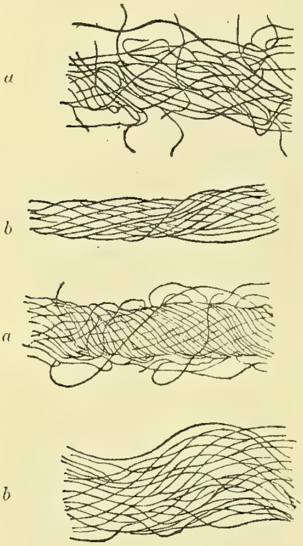
Cloth manufactured by the foregoing processes properly performed, and finished as directed, will be lustrous to the sight, soft and pleasant to the touch, and of a durable quality. The nap will be short and perfectly laid, so that dust will not penetrate it but lie on the surface, and admit of easy removal by brushing; it will not readily absorb water, neither will it shrink when wet, nor show rain-spots from a shower. When being made into garments, it will neither shrink with wet nor under a hot iron, and will long present a new appearance. When it begins to fade, the freshness can easily be restored by sponging and brushing.

Cloth is sold by the running yard, width is stated in inches, the substance is ascertained by the weight, and the quality by a gentle pressure of the hand of a competent judge when being drawn over the surface.

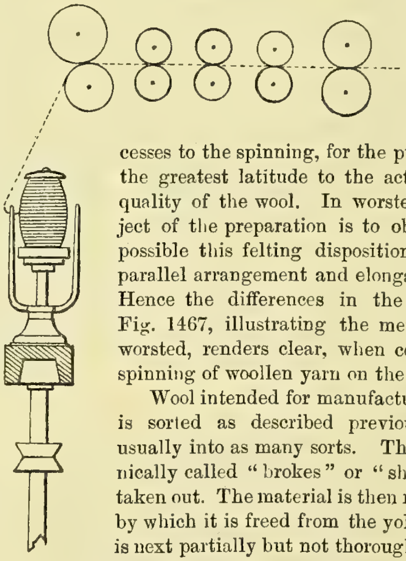
Worsted.—The second great textile industry founded upon wool as its raw material is the worsted manufacture. As observed previously, the wools of commerce are divided into two great classes: clothing wools and combing wools, otherwise short wools and long wools. The former at one time were almost exclusively used in the woollen trade, and the latter in the worsted trade. Owing, however, to the improvement in machinery that has been accomplished during the past 20–30 years, this distinction has to a great extent been obliterated. The invention and development of the combing-machine has enabled manufacturers to comb any free, firm-stapled, clothing wool, having a staple of 1 in. and upwards. Fine Botany yarns are now commonly spun and used in the worsted trade. On the other hand, combing wools are quite as frequently used in the woollen trade.

The essential distinction between woollen and worsted yarns (Fig. 1466) will be found in the arrangement of the fibres peculiar to each class of yarn. In the woollen yarns, *a*, the fibres are purposely entangled and crossed, and all drawing is avoided, in the preparation, in order to leave undisturbed the natural curvature of the fibre, and this arrangement is endeavoured to be preserved through all processes to the spinning, for the purpose of affording the greatest latitude to the action of the felting quality of the wool. In worsted yarns, *b*, the object of the preparation is to obliterate as far as possible this felting disposition, and secure the parallel arrangement and elongation of the fibres. Hence the differences in the processes, which Fig. 1467, illustrating the method of spinning worsted, renders clear, when compared with the spinning of woollen yarn on the mule.

1466.



1467.



Wool intended for manufacturing into worsted is sorted as described previously, though not usually into as many sorts. The short wool technically called “brokes” or “shorts” is carefully taken out. The material is then ready for scouring, by which it is freed from the yolk and grease. It is next partially but not thoroughly dried, as when being prepared for woollen yarn, often not being placed on the drying-stove at all, but simply put through the pair of squeezers or pressing-rollers as it passes out of the scouring-bath, whence it is conveyed to a carding-machine much like the scribbler or first carding-engine in the wool set. Here it is opened, cleansed, and carded, by which it is to a certain extent relieved from its grosser impurities as well. From this machine, it is doffed in the form of a rope sliver, and wound into a ball, for the supply of the combing-machine.

The first attempt to construct a mechanical wool-comber was made by Dr. Cartwright, the original inventor of the power-loom. This comber, though not much more successful than the same inventor's previous efforts, suggested the idea and formed the basis upon which succeeding mechanicians laboured to accomplish the end he sought. The first who made any decided advance upon it was Hawkesley, of Nottingham. His efforts were followed at a long interval—about 35 years—by the more successful attempts of Platt and Collier, which was a great improvement. A considerable number of these machines were adopted by manufacturers, and many have remained in use until within a recent date. In 1842, Donisthorpe made a further decided step in advance, and again in 1844.

The process of combing by hand, though it had been in vogue for ages, had several serious defects. The principal of these was that during washing the fibres got considerably entangled, and when the wool came to be combed, these crossed fibres would coil around the teeth of the comb when the wool was lashed into them, and which in fact it was necessary should be the case in order to secure its withdrawal and the combing of the portion under operation. When, however, the part left upon the holding comb came to be taken out, it was so firmly lashed around the pins that a great portion of the long fibres required to be broken in order to get it out, thereby increasing the quantity of “noil ” or waste, and diminishing the “top” or best portion. The plans of all the inventors who worked at the problem of effecting combing by mechanical appliances were based upon this idea, regarding it as an essential element, and therefore in all their designs and achievements this serious defect reappeared.

Josué Heilmann, the French inventor of the celebrated machine known by his name, however, revolutionized this process of combing by the new principles he embodied in his invention. The essential parts of the important improvement are as follows. The framework contains two jaws, or nippers, through which the prepared wool is fed into the machine; when the fleece has passed sufficiently through, these close upon and hold it firmly. That part of the revolving drum which is armed with comb teeth then passes up and combs the end hanging out, the nippers holding the wool firmly and securely in this position whilst it is combed by the passing drum. In the forward revolution of the drum, the plain part of its surface passes up and presses against the uppermost of the drawing-rollers when they are in their uppermost position; at the same time it gathers up the cleaned end of the fleece, and passes it between the drawing-rollers. The upper roller is turned by the friction of the drums, and the lower roller by pressure from the upper roller, thus a tuft of wool is detached from the fleece, and again held by a second pair of nippers. As soon as the roller and drum have taken hold of the cleaned end, the first pair of nippers open, and, in the act of opening, press the fleece up into the teeth of the comb, at the same time that another comb is caused to fall into this fleece, and thus, as the tail end is detached, it is also partly cleaned by being drawn through these combs. The tuft is now entirely held between the two drawing-rollers, which, with their framework, are caused to travel down from their uppermost position to the lowermost one which they occupy, at a greater speed than the surface speed of the drum; the lower of the two drawing-rollers is then brought into contact with the plain part of the drum, causing the rollers to turn in a contrary direction, so bringing back the partly combed tail end of the tuft, which is held until it has received a second combing from the succeeding portion of the drum furnished with comb teeth; the rollers then deliver the thoroughly cleaned tuft and return into their former position to repeat the operation. A continuous sliver is formed by each succeeding tuft being so laid as to slightly overlap that which has gone before, and it is then passed forward into the can by the conducting-rollers. The card-rollers are for the purpose of brushing the noil out of the teeth of the drum, and this is pushed out of the teeth of the drum by a doffing-knife, and carried away by conducting-rollers.

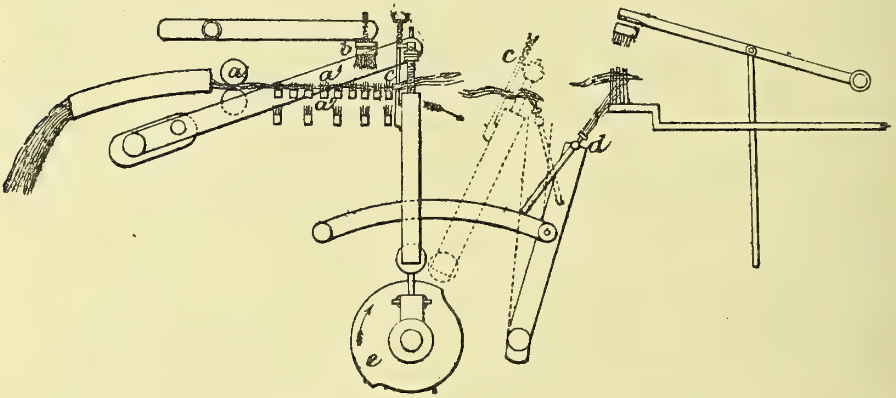
The introduction of the nipper principle into the combing-machine constituted a great advance over the preceding plans. Succeeding inventors therefore embodied it in their improvements, the result being that a great amount of litigation was engaged in before the rights of each could be clearly defined. Lister and Donisthorpe had invented a plan of combing wool, which, though accomplished by slightly different means, embodied Heilmann's principle; the consequence was that an action was commenced by the proprietors of Heilmann's patent, who secured a verdict in their favour. Lister thereupon made arrangements with them, whereby he secured the sole right of its application to wool-combing for the sum of 30,000*l.* This was done, not with the purpose of using the machine as made by Heilmann, but to secure the unmolested right to use and amend his own, which was considerably superior. Lister subsequently took out a number of additional patents, which were merely variations of the first, and intended only to prevent any colourable evasion though real infringement of his rights. Since 1852, when the purchase above mentioned took place, the machine as made and vended is said to have returned to the owner an immense sum of money.

The essential parts of the combing-machine as constructed by Lister & Donisthorpe are shown in Fig. 1468. The comber is combined with a screw-gill frame, the feed-roller *a* and the gill-bars *a a* of which, conduct the material into the machine, the tail end of each tuft of wool being combed as it is drawn from the last gill-bars. The brush *b* descends and presses upon the fleece every time that the nippers detach a portion, to prevent it rising out of the pins. There is a pair of nippers *c*, the upper jaw of which consists of a broad blade with a sharp edge, which is a fixture, and the under one of an upright bar which is caused to slide up and down by the revolution of the tappet *e*; this under jaw has a grooved surface, into which the edge of the blade is inserted at each nip. A carrier-comb *d* takes the tuft from the nippers, and places it upon or rather in the teeth of the circular receiving-comb *f*, of which only a section is shown. A brush *g* drops into the points of the teeth, and presses the tuft down into a proper position for being drawn off. The illustration shows the nippers in position to detach a tuft from the gill-bars; when they have closed upon it, the framework in which they are held is made to traverse the arc of a circle into the position shown at *h*; there the carrier-comb advances to the same position, and pushes its teeth into the end of the tuft, just as the nippers open to release it; the carrier then passes away from the dotted position, and, in those to which it passes, transfers the tuft to the receiving-comb. The portion deposited here is drawn away in a continuous sliver, and, as it is the dirty end or noil which is placed upon the circular comb, this is cleaned by being drawn off, the noil left being removed in the usual way by a knife-lifter and conductor-rollers.

Numerous improvements have since been made in the wool-combing machines, but all have been based upon the inventions of Heilmann and Lister & Donisthorpe. It is unnecessary to trace these further, as the principle will be thoroughly understood from what has already been stated. Fig. 1469 is a perspective view of a wool-comber which is highly esteemed in the trade.

The introduction of mechanical combing has been a main cause of the great development of the worsted trade, as a single machine will comb a greater quantity of wool than 100 men could do by hand, and that in so much better a manner in every respect as to make it exceed the hand process as much in quality as it does in quantity.

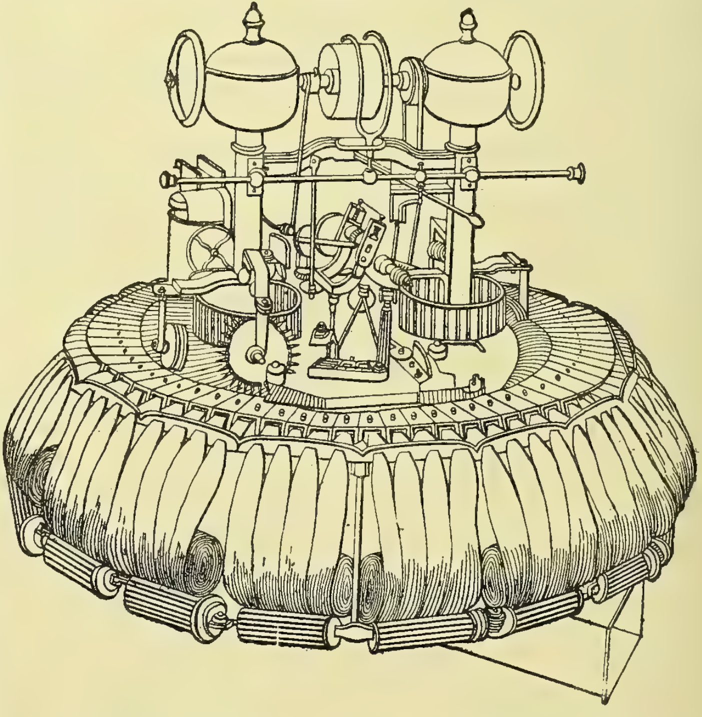
1468.



Drawing.—The process of drawing is partly intended to complete or perfect that of combing, namely to secure the parallel arrangement of the fibres of the wool, and to take from them their wavelet or undulating form, and, by elongating the fibres in that manner, to secure the greatest length. This is accomplished by the application of heat in the drawing processes. The sliver is also attenuated and reduced to fit it for the spinning process.

The "set" of drawing machinery usually consists of 6 frames or screw-gills. The screw-gill drawing-frame is composed of an iron reservoir or steam-chamber placed in advance of the feed-rollers, the latter of which deliver the sliver to a series of gill-bars which travel from the feed-rollers in the grooves of two screws laid parallel to each other. These gill-bars are furnished with two or three rows of pins. When they have arrived at the end of their traverse, they drop into the grooves of two other parallel screws arranged below the first pair for their reception, and by which they are carried on their return to a point below that from

1469.



which they started, when they are elevated into the first position by the action of two cams, one on each screw. The screw-gill drawing-frame being fully described in the article (see pp. 1180–1) on Jute Manufactures, the reader is referred thereto for fuller particulars. The differences are in points of detail merely, occasioned by the respective natures of the material they are constructed to work. The steam-chamber is one of these.

As soon as the slivers leave the combing-machine, a given number, say about 16, are placed upon a feed-table and divided into two sets, each of which is passed first over the heated chamber by which the slivers are softened and better adapted for the drawing process, then through two sets of coarsely-fluted rollers which serve as feed-rollers. As the wool is delivered from these, the gill-bars rise, and the pins entering it conduct the material to the drawing-rollers. These rollers move with a velocity considerably greater than the feed-rollers, say 5–6 times or more, taking the wool from the latter in an even and regular manner; and attenuating the combined slivers from their original volume by as many times as the drawing-rollers exceed the feed-rollers in surface velocity. The several drawings are passed into a coiling-can, by which they are loosely twisted into one. Eight of these drawings are next passed through the second frame, and elongated in the same manner, the process being repeated a third time. In the fourth passage through a similar machine, the material is received and wound upon two bobbins, carried upon two large spindles, having large fliers, by which the drawing is slightly spun or twisted, after which it is called a "slubbing." In the fifth frame, the travelling gills are replaced by four sets of rollers, through which the wool is passed, 16 slubbings being arranged in sets of 4, each set being further attenuated, slightly twisted, and wound upon four bobbins. The sixth is the last and finishing process of drawing. In this, three of the slubbings from the last frame are again attenuated, twisted slightly, and wound upon bobbins as before.

The set of drawing-frames thus consists of 4 gill-boxes, the last of which delivers its material in spindles, and two roller drawing-frames, which receive it in the same manner.

Roving.—The "slubbing," having been sufficiently prepared, is ready for the roving process. This is simply a further attenuation of the coarse and loosely-twisted strand of wool to fit it for spinning. In this set, there are again 6 machines, all alike in principle, each doubling and delivering the preparation finer than its predecessor. A slight twist is imparted in each case to secure cohesion. After having passed these machines, the roving is sufficiently reduced, and yet possesses strength enough to pass into the next stage without parting asunder.

Spinning.—Spinning is the last process in the formation of the thread, and in worsted is performed on the continuous principle by the throstle or cap-spinning machine. This is constructed on the same principle as the preceding machines, only differing in the parts being smaller and the spindles more numerous. The latter are vertical, and rest in a footstep-rail having a bolster or bearing-rail fixed above the wharve. A traverse-rail which carries the bobbins is made to ascend and descend by means of a heart-shaped cam. This traverse enables the yarn to be laid upon the bobbins in even layers. Each spindle is mounted with a flier or cap, the former having curls at the extremities of the flier branches. The rovings are conducted from the creel between two rollers, the lower of which is longitudinally fluted; next through or between three pairs of carrier-rollers, which simply bear the rove to the front or drawing-rollers, by whose accelerated speed it is finally attenuated. Being attached to the bobbins upon the spindles, the twist or twine is put in according to requirement, a given number of turns to the inch, which is easily regulated by a change pinion. For 30's yarn, there are usually about 10 turns per inch. (See Fig. 1467, p. 2088.)

Worsted weft or filling is mostly spun upon the pirns, ready for the shuttle of the loom; whilst warp yarns are spun upon the flanged bobbins, from which they are wound and warped in a manner scarcely differing from the processes of the cotton trade. There is, however, only a small quantity of worsted yarn used for warp purposes, as, since the introduction of cotton warps, these have been (except for special purposes) almost universally adopted. They consist of good 2-fold yarns, the bulk of which are spun and doubled in the Bolton and Oldham spinning districts of Lancashire.

The system of spinning worsted, thus briefly outlined, is that known amongst practical men as the English system. For half a century, the trade of the worsted manufacturing centres of this country, based upon this plan, has been conducted with uninterrupted progress and prosperity. Of late years, however, owing to a complete change in the current of fashion, which has been diverted to softer fabrics capable of conforming more easily and gracefully to the outlines of the female figure, worsted goods as hitherto produced in this country have been much neglected, especially for costume purposes. The consequence has been a great decline in the demand, unprofitable trade, and diminished employment for the work-people. The return of worsted fabrics to public favour has been anxiously waited for, but without success. This adverse state of affairs has induced much discussion, and has brought into prominent consideration the advisability of adopting the French system, by which fabrics are produced very much better suited to present requirements. The chief cause of hesitation seems to be a prevalent doubt as to whether the taste of the public is more than temporarily alienated from fabrics produced on the English system, and whether the investments necessary for a change to the French plan might not prove a total loss. There are persons who assert that the change of fashion is not in the direction of good taste, nor in harmony with those natural principles that underlie the art of dressing. Others again dispute this conclusion, and believe the opposite, and that the change of fashion marks a decided advance in the recognition of true principles, and as a consequence it will be perfectly futile to hope for the return of Yorkshire worsted fabrics to popular favour. To this view the writer inclines. From these statements it will be obvious that any change will for a time at least not be more than partial, and that success on the part of the pioneers of the movement will have to be assured before the step becomes anything like general.

The radical difference between the English and French systems of spinning worsted lies in the fact that all the processes of the preparation are conducted without twist being imparted to the material, and that the spinning is performed on the mule-frame in place of the throstle. Another important point of divergence is, in some instances at least, in the French plan the wool is worked dry, that is without oil, but this is not to be recommended. Starting also with a softer staple of wool, all these differences are in favour of the production of a soft fabric, that will drape easily and gracefully, and so meet the present requirements of the *modiste*.

When the fact is considered that the wool fibre is covered with scales, it will be apparent that to twist them together in the preparatory stages, in which a great deal of doubling and drawing has to take place, can hardly be a wise proceeding, as the scales are sure to interlock with each other, especially when insufficiently lubricated, the consequence being that when the drawing takes place the fibres are strained and to some extent broken, whilst a hard and wiry yarn is the product. By the plan of avoiding twist until the spinning stage is reached, the drawing is rendered easier, less waste results, and a softer yarn is produced, which is more bulky in relation to the weight.

With the object of aiding the introduction of this system into this country, an eminent firm of machinists has paid great attention to perfecting a series of machines for the English market, by which yarn can be spun on the French system. The initial stages for several steps are alike. After they begin to diverge, briefly described they are as follows:—

1st Process: *Carding.*—In the carding-engine, the undried wool from the washing-machine is carded. It is spread by hand upon the feed-lattice, whence it passes through a pair of feed-rollers and successively into contact with three burr-rollers, the first of which is 18 in. diam. and steam-heated, the second 9 in., and the third 12 in., each having guard rollers and boxes for the reception of burrs. The burr-rollers are covered with steel teeth. This triple arrangement is an improvement upon the single-roller system. The clothing of each differs from the preceding, being graded from coarse to fine; the effect is that the first roller throws out the coarse, large burrs; the second, those of medium size; whilst the third cleans out the finest burrs, seeds, &c. An oiling apparatus is fixed so as to discharge its contents on the wool at this stage, when oiling is held to be desirable. From here, the wool enters into the breast, the cylinder of which is 36 in. diam., and is provided with three pair of workers and strippers, respectively 8 and 3¼ in. diam. There are two swifts, each 50 in. diam., with a complement of four workers and strippers of the same dimensions as those above, fancy and stripper, and angle stripper. The sliver is stripped and balled by a calender-delivery and balling-head into balls 16 in. long.

2nd Process.—7 balls from the carding-engine are put into the screw-gill balling-machine, and doubled into one with a draft of about 5. The object is to straighten and draw the fibres into parallel order more perfectly. The machine has one head of one delivery, gill-screws to carry 12 gill-bars, and balling motion with surface rollers.

3rd Process.—The balls from the preceding machine, to the number of 10, are next supplied to the screw-gill lap-machine, the function of which is to reduce the round slivers of the balls to a flat sliver or lap, to suit the combing-machine, which comes next in order. It has one head of one delivery, fluted rollers back and front, and screws for the same number of gill-bars as the preceding, the fallers having brass gills double pitch, and the rollers weighted with racks and friction-pulley.

4th Process.—Combing is performed on Little & Eastwood's patent combing-machine, which is a very compact and highly efficient machine, nearly all the working parts being placed inside the circular comb of about 40 in. diam. The gill-head is put within the circular comb, and is fitted with 8 gill-bars. Inside the circular comb is a cylinder, around whose circumference 6 pairs of nippers are arranged. A stripper removes the noil, and a stop-motion arrests the action of the machine when the sliver accumulates on the drawing-off rollers. Its action is as follows: The wool is fed into the fallers of the gill-head by feed-rollers having an intermittent action; the end of the lap is seized and held fast by a pair of nippers on the cylinder, while the feeding head recedes and draws the wool through the teeth of the fallers, combing one end of the tufts by this operation. When the lap is nearly pulled apart, a spring divider thoroughly separates it, leaving a tuft of combed wool in the nippers on the cylinder. The revolving cylinder next carries the tuft over and deposits it on the pins of the circular comb, the uncombed portion or noil ends being left inside the circle behind the pins; this end of the wool is then combed by being drawn outwards through the teeth of the circular comb by means of the drawing-off rollers. As the circular comb receives the tufts of wool with one end combed, the whole of the noil being placed behind the pins, its action is quite free, and little strain is put on the pins; the brushes and drawing-off leathers have diminished work; the fibres of the wool are better preserved; and the wear and tear of the working parts is reduced to a minimum. This structure of machine possesses great capability, being well adapted for Australian, Cape, River Plate, and similar wools. It is especially suitable for short wools, and in long wools will comb up to 6–7 in. in staple. Its delivery is arranged to double three into one: that is, as the sliver from the drawing-off rollers is delivered into the can, it may be so set as to take one or two other slivers along with it. In the combing process, therefore, with drawing three into one, the drawing after passing through the comb is altogether nine into one.

5th Process.—In this, nine slivers from the comb are combined in one by means of the screw-gill balling-machine, the draft being about four. It presents no important features of difference from the one described before, except being doubled, having two heads of two deliveries each, two sets of gill-bars, and brass gills of double pitch. All these particulars can be varied according to requirement.

6th and 7th Processes.—The sixth process is that of back-washing. In the English system, it is regarded as desirable to wash and clear the wool before reaching the comb, whilst in the French plan this is deferred to this point. The back-washer contains two washing-troughs, each fitted with two immersion-rollers; two sets of squeezing-rollers, and five copper drying-cylinders. It has one head of two deliveries, with front and back rollers fluted, screws for twelve gill-bars, balling motion, and creel for eighteen balls. The wool leaves this process thoroughly cleansed from oil and earthy discoloration, and is further drawn and straightened. It works with a steam pressure of 5–10 lb. a sq. in. in the drying-cylinders, which are without bearings on one side to permit of the wool being easily passed over them. It will efficiently wash and ball 800–1000 lb. of wool in a day.

8th and 9th Processes.—Repeated passages through the screw-gill balling-machine, as described in the 5th process, after which it is ready for the next stage.

10th Process.—This is the first process of drawing. In it, the sliver-balls are brought from the last machine, and are doubled two into one with a draft of about four. The slivers first pass through feed-rollers, then over a porcupine-roller, next between a pair of front rollers, whose speed being greater than that of the porcupine, the fibre is drawn and straightened through the teeth of the latter. After this, it passes between "rubbers," which carry it forward and deliver it upon a bobbin actuated by a calender-roller. The machine contains eight porcupines and eight pairs of rubbers, and balls the material on four bobbins 14 in. traverse, two threads upon each, and each of which is reduced from two balls, requiring therefore 16 balls in the creel. It can be made for six, eight, ten, or twelve bobbins if required.

11th and 12th Processes. Second Drawing-frame.—Repetitions of the preceding operation, and on a similar though rather smaller machine. The sliver from the foregoing is doubled two into one with a draft of about four, as in foregoing operation. The bobbins in this case are of 12½-in. traverse.

13th Process. Reducing.—Again a process similar to the last. The slivers are again doubled two into one, and attenuated by a draft of four, by which they are again reduced to half their former dimensions. The machine has four boxes, eight porcupines, eight pairs of rubbing leathers, eight bobbins of 7-in. traverse, and creel for two heights of bobbins.

14th and 15th Processes. Slubbing.—Both similar to the preceding, but the doubling is four into one, with a draft of four, giving sliver of the same dimension. Bobbins 7-in. traverse, two threads being wound upon each.

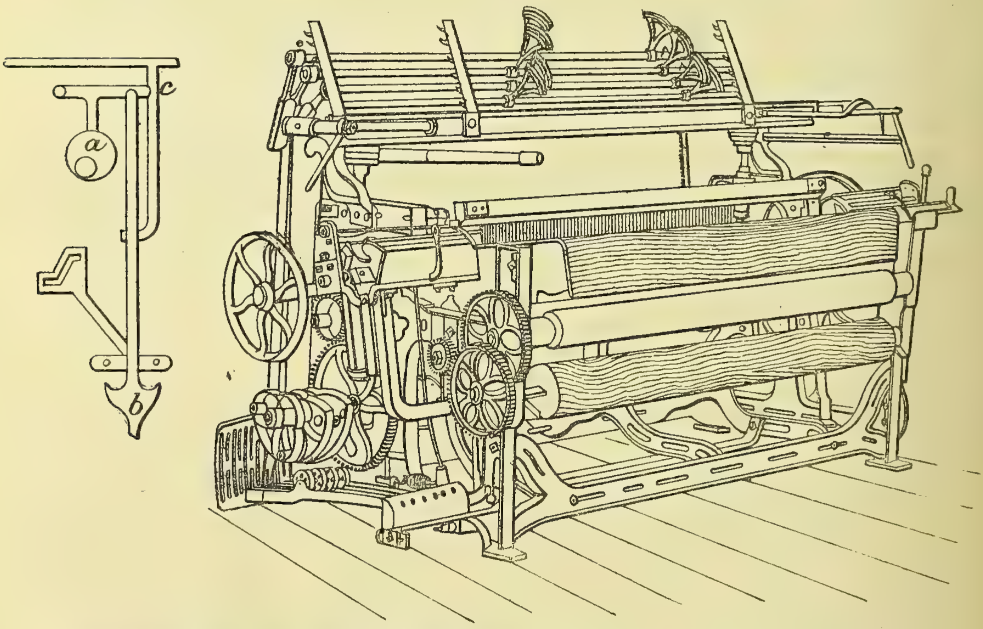
16th and 17th Processes. Roving.—Substantially the same as the foregoing, and performed on the same class of machine, though somewhat smaller. Doubling four into one, and drawing four.

18th Process. Finishing roving.—This is the last stage of roving, and again the machine is similar to the preceding. The doubling is however two into one, with a draft of four. This last machine contains four boxes, eight porcupine-rollers, eight pairs of rubbers, and creel for four heights or 16 bobbins. The finished roving is received on eight bobbins of 7-in. traverse. The machines for all the preceding processes from and including the tenth, are similar in construction and principle, varying only in size and very slight details; the latest ones are smallest. To secure freedom from vibration, which would injuriously affect the quality of the processes, the head-stock is built upon a strong base-plate, which prevents vibration from the gearing and the rubbing motion. The different parts are so constructed as to permit changes to be made with the greatest facility, to secure steadiness in working, so as to prevent any cutting of the wool, and finally to obtain durability in the machine. Through all the preceding stages, there has been no twisting of the fibres, consequently no straining or damaging of the fibre, either by destroying its elasticity or injuring its scaly imbrications. It arrives at the stage in which it has to assume its final form with all its qualities intact, and in the best condition for being subjected to severe torsion and the strain of a great draft. A four-hank roving is drawn and twisted simultaneously by a draft of ten, so as to make a yarn of 40's count.

19th Process. Spinning.—The final machine of this series is the mule, and, not as in the English system, the throstle-frame. Platt Bros. & Co., Limited, of Oldham, the makers of the different machines thus briefly described, have introduced several important improvements in this machine. The one attached to the series of machines under notice contained 300 spindles 16 in. in length and $\frac{11}{16}$-in. gauge, and was fitted with four lines of rollers, the lower one of each line being case-hardened, and the front top rollers being of wood covered, and having case-hardened iron pivots, weighted by saddles and levers, the three rear-line top rollers being simply incumbent upon the lower ones; it had also the double rim-band arrangement, and conical friction-box for working the cam-shaft and taking in the scroll-shaft. By newly invented appliances, the carriage can be stopped, or rather will be stopped automatically, at any point of its course, either in coming out or going in, by the presence of any obstruction, and the spinning operations will cease automatically should the cam-shaft make its change before the appointed time. New means are adopted for regulating the tension of the backing-off chain during the depression of the faller-wire to the spindle-point, preparatory to commencing the backing-off. An automatic arrangement for forming the upper cone of the cop, technically called a "nosing" motion, is included in the various improvements, and also a patent winding-on motion, by which the winding is automatically adjusted to the enlarging form of the cop. These improvements constitute this mule not only a novelty for spinning worsted in this country, but also a more perfect machine for its purpose than any existing upon the Continent from which the general idea has been borrowed. Many of the novelties have been transferred and adapted from the cotton-spinning mule.

Weaving.—Passing the intermediate processes after spinning, as not differing in any feature of importance from those in other divisions of the textile trades, we come to weaving. Here again there is little to distinguish it from the same branch in the cotton trade, to which it bears a close resemblance in details. There are a great quantity of fabrics made in a plain weave, though not to such a proportion as in cotton. In the worsted trade, the complicated weaves are proportionately much more abundant, and the jacquard a far more frequent adjunct of a loom. The plain loom, as it is called, is usually fitted to weave orleans, alpacas, mohairs, and twills up to 6–8 shafts.

1470.



About the first departure from this class of loom is the one represented in Fig. 1470. It is a single-pick rocking-box loom, with a two-holed shuttle-box, and weft motion at each end. The cylinder and boxes are on the ordinary plan, but a tappet *a* is introduced upon the top or single-pick shaft, which elevates a rod having a double-catch *b* at its extremity, connected with a slot motion working in the inclined slot-groove. In this groove works a single stud, projecting from a horizontal square rod placed parallel with the bottom shaft. At each end of this rod is fixed a clutch, which can slide the tappet backwards and forwards on any single pick whenever required as directed by the arrangement of the cylinder. Three levers are provided on the cylinder, the middle one working the tappets, the inside one the boxes at the cylinder end, and the outside one the boxes at the driving end, the motion being transmitted through a small rod in proximity to the spur-rail.

1471.

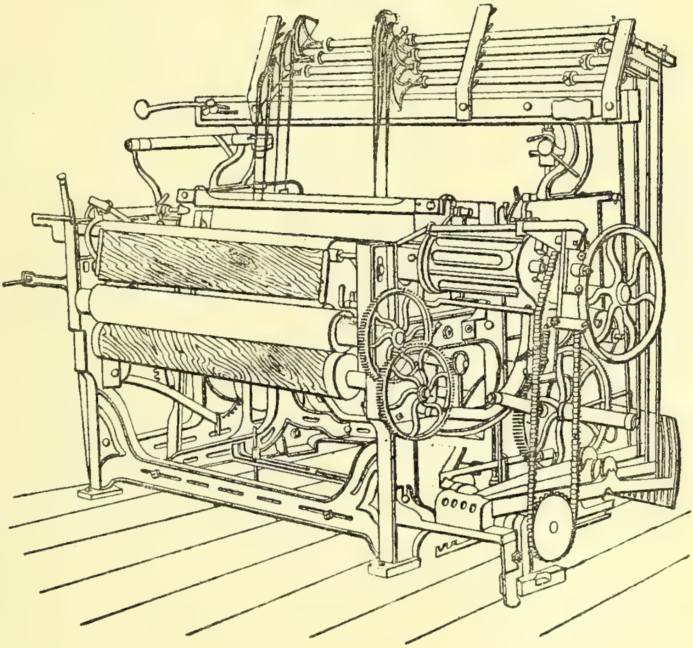


Fig. 1471 represents a loom constructed for a wider range of work than the preceding, being adapted to weave complex checks requiring a variety of colours. Its treading or shedding arrangement is similar to the preceding, but differs in its box capacity, 6–8 or more boxes being arranged around a common centre, and caused to revolve by an endless chain from a star-wheel in connection with a pegged-wheel actuated by a three-rise tappet on the bottom shaft. A card motion having an eccentric and ordinary cylinder connects this tappet with the catches. A novel arrangement, however, is introduced into this loom in the shape of a sliding bowl between the three-rise tappet and the upright lever that moves to every double pick, and draws the drag catches that pull round the boxes. This sliding bowl is actuated by the cylinder, which slides it backward and forward to or upon any of the elevations of the three-rise tappet, as required, two cylinder pegs of different lengths being used to effect this object. The movements can "skip" or pass over any of the shuttle boxes, according to requirement, with facility and ease, so as to bring any desired shuttle into work. The complicated mechanism of this class of looms has been within recent years brought to great perfection, thus giving certainty of action and relatively great speed.

Into the finishing processes of this branch there is no necessity to enter.

Carpet (Fr., *Tapis*; Ger., *Teppich*). The carpet manufacture forms a considerable branch of the worsted section of the textile industries. Floor-coverings are of great antiquity, and in general use amongst both savage and civilized races. They were most probably suggested by the verdant clothing of the earth's surface, and consisted in early times of leaves, grasses, rushes, straw, and similar substances of vegetable origin. Amongst pastoral races and those addicted to hunting, the skins of domestic animals and of those slaughtered in the chase were at an early time utilized in the same manner. It is not improbable that the art of weaving had its origin in the endeavour to obtain a cleanly and more comfortable article than leaves and rushes. This was realized by plaiting or interweaving reeds from the river-bank in a manner which has survived to this day. In tropical climes, and the warmest of the temperate regions, these woven mats are still extensively used; especially amongst the poorer classes of society. With the development of the art of weaving, more luxurious coverings were devised, for which a ready demand was found amongst the rich. Ancient civilized nations very early attained great skill, and displayed a high degree of refined taste in the designing and manufacture of carpets. China, India, Persia, Turkey, and Spain, under the Moorish dominion, are stated to have attained excellence in this respect. According to accepted canons of taste, the work produced in Hindoo, Persic, and Turkish looms, yet stands in the front rank, if not in the very first position for its indisputable elegance of design and quality of product. Of late years, however, it is complained that these characteristics are undergoing deterioration, as contact with European peoples is degrading the former, and making the artistes acquainted with the processes of sophistication.

Coming to the present times, it need only be remarked that as carpets are articles of general consumption in all civilized countries, their manufacture is very widely spread. In this country, Kidderminster stands at the head of the districts where the industry is carried on; Wilton, Worcester, Rochdale, Halifax, Dewsbury, Durham, and several towns in Scotland, also participate in the trade. The Continent receives a large portion of its supply from the looms of England, though factories exist in some countries there in which high-class fabrics are produced. Of late years, a great development has taken place in the carpet manufacture of America, stimulated by the prohibitive tariff that has been applied to foreign productions. Philadelphia is the centre of the American carpet industry.

Carpets are made of various materials, either unmixed or in different combinations, according to the structure or effect required. A common carpet is produced in jute by the employment of dyed yarns, the effect being obtained by arranging the colours in stripes parallel with the length, a checked effect resulting from crossing these with various coloured wefts (transverse threads). The "Kidderminster" or "Scotch" carpet, as it is indifferently called, is a figured fabric, generally having a worsted warp and a woollen weft, though in low qualities the latter is sometimes of cotton. In tapestries, Brussels, and similar fabrics, the warp is of linen or cotton, and the filling or weft forming the back of cotton or jute, whilst the pile is invariably of worsted.

Until within a comparatively recent period, carpets were woven in hand-looms, but the growing demand and the progress of invention has led to the introduction and extensive adoption of power-looms in this as in all the other textile industries. The different varieties of carpet, however, require different kinds of loom. Fig. 1472 is a representation of one of the best looms for the production of Scotch or Kidderminster carpets. As a great portion of the effect is obtained from the employment of coloured wefts, the loom is fitted with revolving shuttle-boxes, which permit of the employment of as many as 16 shuttles, each containing weft of a different shade or colour. Another important feature in it is the possession of a double-beat lay, produced by the action of a cam, and which enables a clear shed for the passage of the shuttle to be secured, and, the weft being driven closely home, a firm texture is obtained. An improved arrangement for taking up and retaining the fabric as it is produced is introduced, ensuring uniformity of texture. There is very little in this machine in the way of specialities beyond what has been described in preceding articles on the different branches of the textile industries, except the few adaptations needed to render it better suited for its particular purpose. One feature, however, which has not hitherto been described, and which is a chief purpose of its introduction, is the jacquard attachment, a most important adjunct to the loom in nearly all the textile trades.

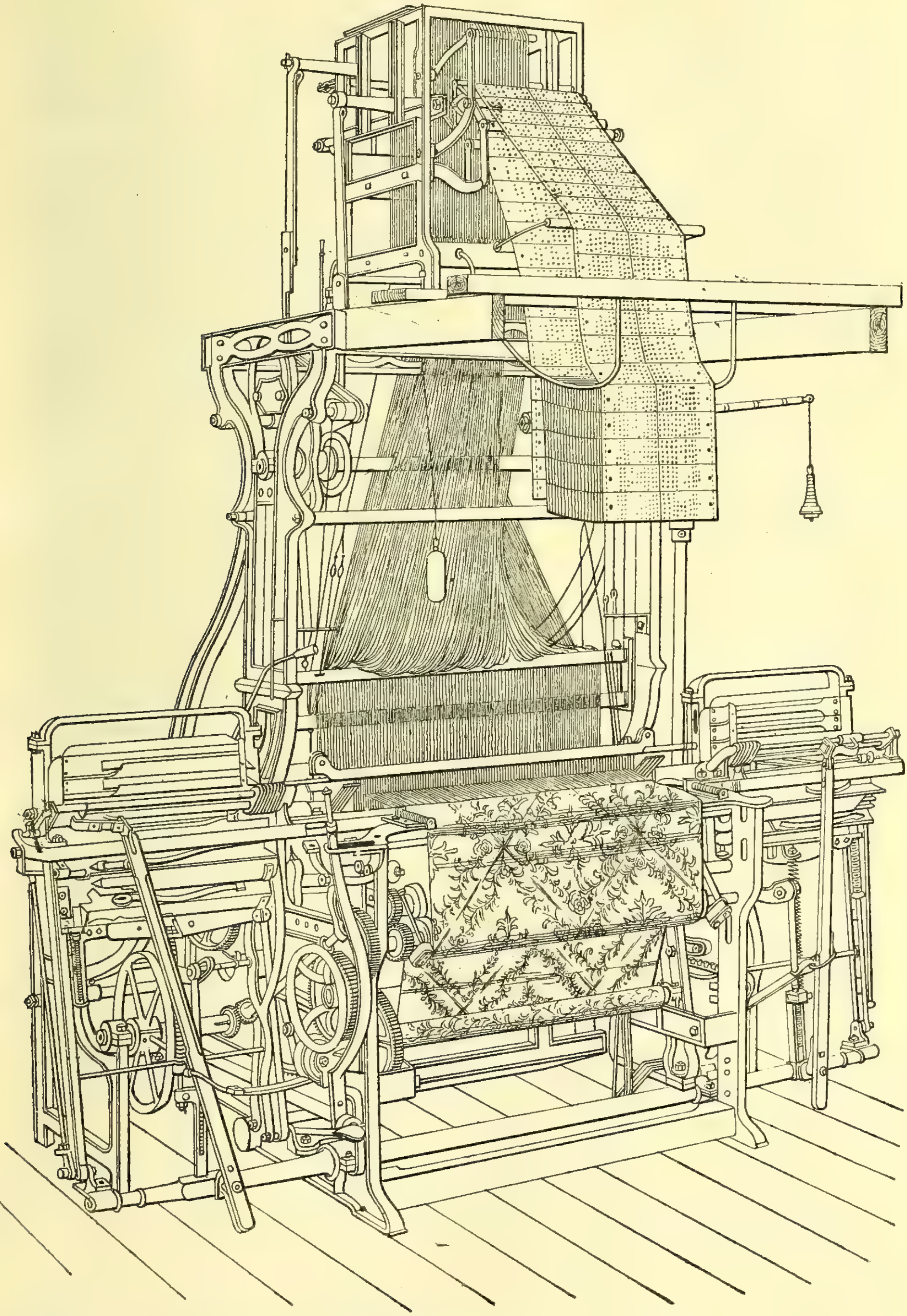
Figured fabrics have been produced in the loom for ages past, but these required great skill on the part of the weaver to fabricate, and were consequently rare and costly, until the invention of mechanical aids to the weaver. These aids gradually increased in number, and were of various degrees of merit. The most important, and the one in general use until about 1820, was the draw-loom, which required the weaver to have an assistant, called a "draw-boy." The boy was afterwards partially superseded by the invention and adoption of a machine called a "draw-boy machine." These plans were in common use some time after the invention of the jacquard, but the great superiority of the latter when its merits become known, quickly secured its adoption. It is simply a development of the draw-loom.

The jacquard machine was introduced into England about 1820, and after that time was soon extensively adopted. Numerous improvements have since been made by different persons, and it has been brought to a high degree of perfection. It was first applied to the hand-loom, and after some time to the power-loom. Its capacity was greatly extended by the invention of the system of making compound harness, and also "split" harness, by two weavers of Bethnal Green.

A brief description of the illustration will suffice for present purposes. The mechanism contained in the frame on the top of the loom, and which constitutes the jacquard, consists of a prismatic roller called the "cylinder," which revolves on its axis. Inside the frame near this is a perforated board, called the "needle-board," containing a considerable number of "needles," usually 200, 400, 600, or 900, and from these numbers the jacquard is named. It is not often that in the power-loom this number exceeds 400. These needles extend horizontally across the frame, one end protruding about $\frac{1}{4}$ in. through the holes in the needle-board in the direction of the cylinder, whilst the other terminates in a box on the opposite side of the frame, called the "spring-box," because each needle at this extremity is fitted with a fine spiral spring, the whole of which are contained in this box. In the centre of the length of these needles, a loop or eyelet is formed, through which wires are vertically passed having hooks at both extremities, the lower ones being attached to the descending cords called the harness, which again are connected with the leashes containing the mails or eyelets in their centre, through which the warp threads horizontally pass. The tops of these wires are bent to form an acute-angled hook, almost like the barb of a fish-hook

Above these hooks, is a frame composed of several bars, called the "griffe," which is made to ascend and descend alternately, the bars fitting into the angle of the hooks. The "cards" are strips of cardboard about $\frac{1}{8}$ in. thick, closely perforated with round holes to receive the ends of the horizontal needles. These cards are laced together so as to form an endless web, and the web is placed over the cylinder. At each extremity of the card is a larger hole, into which fixed pins on the cylinder enter, and by which they are carried round. The loom having been provided with

1472.

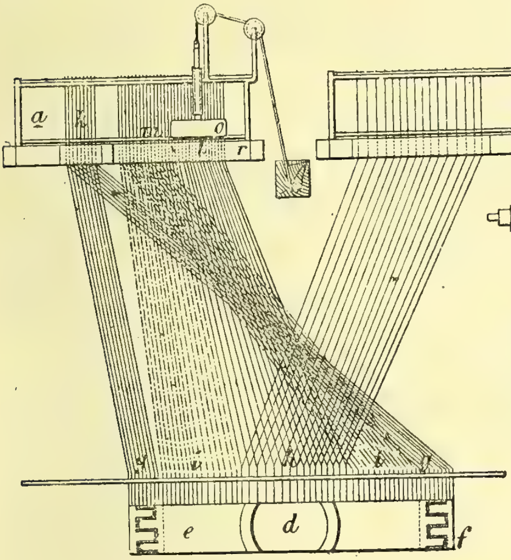


warp, and the proper connections established between the different parts, it is ready to commence work. The cards are perforated to produce the design required, and according to this the pattern is woven. With the commencement of weaving, the card cylinder begins to revolve, bringing up the cards on the inside of the jacquard-frame. The cylinder being carried in a "lay" or batten, oscillates a sufficient distance to allow space for it to be drawn or pulled round by a pawl or lever, by which it is moved. Every movement is the fourth part of a revolution, and brings up a fresh card upon the cylinder, at the same time delivering the most advanced upon it. The cards are so adjusted that each lies evenly on the flat surfaces of the cylinder, and by the oscillation of the batten is brought "square on" against the needle-board. The ends of the needles, projecting about ¼ in. through the board towards the cylinder, enter the perforations of the cards if these happen to be opposite their extremities, and are thus undisturbed, and keep their hooks upright. The griffe having simultaneously descended, its bars catch hold of these hooks, and in rising it draws them upward, and through the harness and the leashes containing the mails lifts the warp threads, opening a "shed" or passage for the shuttle. As only a portion of the threads are required to be raised at once, the others are prevented rising by the following means: When the cards are pressed against the needle-board, those needles which do not come opposite a perforation or hole in the card are pressed back and carry with them their vertical hooks, which are thus pushed out of range of contact with the bars of the griffe. Owing to this they are not drawn up when the griffe ascends. The threads thus left down are usually, though not always, lifted by the succeeding card. It will thus be obvious that there is scarcely any limit to the capacity of the jacquard to produce variety of design, as any single thread of the warp can be raised when required. In the ordinary jacquard, one card is required for every transverse thread or pick of weft contained in the figure or design of the cloth. When these have all passed over the cylinder, the pattern is completed, and a repetition commences. Sometimes these designs are very elaborate, and take many thousands of cards, instances having occurred in the silk and linen trades wherein they have exceeded 30,000. Many ingenious appliances have been invented to diminish the number needed in such cases, but to detail all these is not necessary; a description of one of the most recent improvements will suffice.

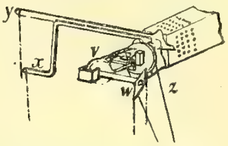
This is an invention patented during 1881 by James Irving, manager for Richardson, Tee, Rycroft, & Co., linen manufacturers, of Barnsley, and which is intended to obviate the necessity hitherto existing of having to change the set of cards in use when weaving goods having end borders or figured centres, or both. The common plan would be to use a sufficient number of cards to work the design right through, but as the use of a great number of cards can be dispensed with by employing one set for the centre figure or border or both, and another set for the ground and end border, and making the change when required, this plan is generally in use. The great drawback to it has been the cost of making the changes, weavers (men) being paid 1–2*d.* for each occasion. This generally amounts to 3*s.*–5*s.* per loom per week, an important addition to the cost of weaving. Where women weavers are employed, it has been necessary to employ a man or two for the purpose of making the changes for them; but as many of these requirements arise at the same moment, much additional time is lost in waiting. In whichever way the changes are made on these plans, 10–15 per cent. of the working hours of the week are lost. As fabrics which require these changes are numerous in all the textile industries, Irving has conferred a service on the trade generally by this invention.

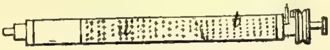
In his first plan, to the ordinary jacquard with which the loom is furnished, he adds a supplementary apparatus of the same kind, which is provided with all the requisites as in the first case, but is smaller. The conjoint apparatus stripped of all unnecessary detail is shown in Fig. 1473. The first jacquard is represented at *a* and the second at *b*. The connection between the two sets is secured by the harness descending from *b*, and joining the harness of the first jacquard at *h*. In the figure, it is assumed that the fabric in process of manufacture is a rectangular drugget, or other article having a central design, which is indicated by *d*, a plain or ornamental ground *e*, side borders *f*, and cross or end borders not shown in Fig. 1473. The lines marked *g h i* indicate the mails, of which, to preserve clearness, a few only are introduced. The mails *g* lift the warp threads, which enter into the formation of the borders, being attached to the hooks of the set of needles at *k*, which are operated by a set of border-pattern cards, shown on the cylinder below them. The mails *h* lift the threads that enter into the composition of the central figure, and are connected with a set of needles at *l*, and also by the additional harness to the needles in the second apparatus. The mails *i* operate the threads that compose the ground which are not woven either into the side borders or the central figure. These are connected with a set of needles at *m* by means of the harness indicated by dotted lines. Above the needles *l*, a plate *o* is suspended, which can be lowered when required between the needles *l* and the cards upon the cylinder *r*, it being of such dimensions that when thus interposed and subjected to the action of the cylinder-batten, it pushes in the whole of the set of needles it covers, thus neutralizing the action of the cards, and throwing the hooks out of contact with the griffe, as long as may be required. This interposition is easily brought about when the weaving of the fabric has progressed to the point where the formation of the central design has to commence. Thus blocked, the mails would remain inoperative, and the warp threads would not be woven into the fabric, were it not for their connection by the lines of the second set of harness with the supplementary jacquard *b*. As soon, therefore, as the central figure has to commence, the weaver stops his loom, interposes the block-plate *o*, on the first jacquard, throwing the set of needles *l* out of operation, and brings the apparatus *b* into gear by moving a sliding clutch which engages it with the boss of a lever from which it receives motion. This brings into action the second set of cards which are perforated to produce the central figure instead of the general ground. When the design is completed, the second apparatus is thrown out of gear, the block-plate *o* is drawn up, and the set of needles *l* are permitted to resume their action. These changes are effected in a moment or two with perfect ease by any weaver, whether male or female.

1473.

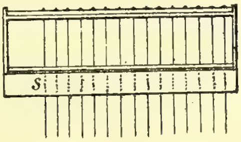


1476.





1474.



1475.

The inventor provides for the needles *l* being put out of gear in a variety of ways, as well as the above. The invention is also applicable to the production of more than one design upon one set of cards, and, in fact, in most cases where the design cannot be produced by one set. Any required number, or the whole of the mails may be connected with the second cylinder, and they may also be connected with the needles, either the whole or any number thereof, on what is known as the "five-end system"; or two or any number of needles may be connected with one needle. The above arrangement is all on the single-end system.

The manner in which the inventor prefers to produce the end or cross border is illustrated by Figs. 1474, 1475, 1476. Fig. 1474 represents a card-cylinder, and Fig. 1475 shows the arrangement of the needles to suit the cylinder. The vertical rows of needles *s* are spaced at twice the distance apart as compared with the rows of holes *t* in the cylinder, and there may be twice as many holes in each face of the cylinder as there are needles. In Fig. 1474, a portion of a card is shown in position upon the cylinder on the part marked *u*. The card is punctured with two sets of holes, the rows of one set alternating with the rows of the other, one set being shown by crosses and the other by dots. One of these sets of holes would produce the plain ground, or ground-pattern, and the other the cross or end border, referred to before. When the changes are required to be made, the cylinder can be moved laterally, in the direction of its axis, by suitable appliances; one means of doing this is shown in Fig. 1476, where it is seen that a gudgeon of the cylinder is provided with a collar, working in a slot in the link of an excentric *v*, which can be rotated to a sufficient extent in either direction by means of the cross lever *w*, whereon cords are attached for the purpose of bringing it within easy reach of the weaver. By pulling one cord, the cylinder moves in one direction; whilst by means of the other, it is brought back. A lateral movement of the cylinder to the extent of half the distance between the vertical rows of needles puts one pattern out and the other into action. In this manner, if desirable, more than two sets of patterns may be produced from one set of cards: thus one set of holes may produce the end borders; a second, the side borders and ground; and a third, the side borders, ground, and central design, thus dispensing altogether with the supplementary jacquard and its furnishings. From various causes, such as the failure of the automatic stop-motion to arrest the movement of the loom when the weft thread has broken, or from the necessity through the occurrence of a fault to unweave a portion of the cloth, the card gets out of proper relationship with the parts of the pattern last woven, in which case it is necessary to reverse its movement with facility and ease. Fig. 1476 shows a means whereby this may be readily done. There are two levers x y, the first being a presser-lever, and the second a catch. Both are furnished with cords at their free ends, by pulling which they can be lifted clear of the cylinder, which can then be turned in either direction with ease and rapidity by means of the endless band z, passing over the grooved pulley on the axis of the cylinder.

The economy effected by the invention will be easily seen from the following statement, which may be regarded as a fair average result of its application. Suppose a loom is required to be mounted for the production of a towel 40 in. long, and 90 picks to the inch. This, under the old system, would require 3690 cards, 600 long, the centre and border patterns being stamped on one card. If these patterns were on separate cards, as on a still older plan, 7830 cards would be required 300 long. By the improvement under notice, 600 cards 600 long will produce all the design. The expenditure on the first-mentioned system, requiring 3690 cards, would be as follows:—Cards, 5*l.* 18*s.*; punching the patterns, 5*l.* 5*s.*; band, 11*s.* 6*d.*; wire and wiring, 18*s.* 6*d.*; lacing, 1*l.* 7*s.* = 14*l.* The improved form would be: for cards, 12*s.* 8*d.*; punching, 18*s.* 8*d.*; band, 2*s.* 2*d.*; wire and wiring, 3*s.*; lacing, 4*s.* 6*d.* = 2*l.* 1*s.* In an economical point of view, this is of considerable importance in an establishment having a considerable number of looms.

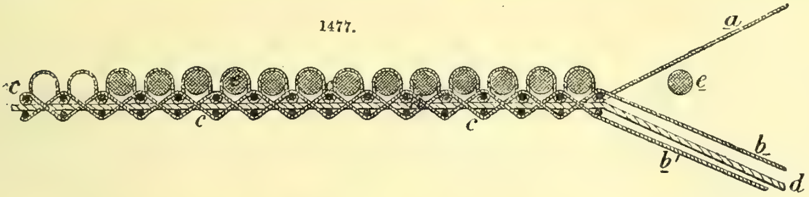
This heavy expenditure on the old plan has, however, led to the extensive adoption of the alternative method of changing the cards detailed above. But owing to the cost and the loss of time during working hours, it is questionable whether it is really of any considerable advantage. Also it may be remarked that any change in the length of the towel necessitates a corresponding change in the number of cards, which is a source of delay. The 600 cards on the improved plan weave any length required, and the change from the body to the border pattern is effected without stopping the loom. In fabrics having a medallion centre, on the plan generally in use, 1800 cards are required for border and filling in addition to the ordinary set, and these need to be changed six times during the weaving of each cloth. This improvement requires only an addition to the ordinary set of the actual cards used in weaving the centre figure, whilst changing is altogether dispensed with. Its advantages will therefore be fully obvious.

In carpets such as Brussels, tapestry, and pile fabrics generally, the body, backing, or foundation forms the true fabric, with which the pile-threads are interwoven. The latter are usually of a different material, and are interwoven in such a manner as to form a terry, looped, or pile surface. The weaving of these articles differs only little from that of plain fabrics or those woven by the jacquard. All that is required in addition is mechanism by which the pile-threads can be formed into loops on the surface during the process of weaving. There are several plans of doing this, but the one in highest favour is that wherein wires are introduced into the "shed" or opening formed between the body and the pile-warp, and which, when the threads of the latter have been woven down into the body-fabric, are withdrawn, leaving a line of loops across the width of the fabric. Previously to 1850, nearly all carpets of these kinds were woven by or on hand-looms. This was a laborious occupation, and the production of each weaver was a small length per week. There have been considerable improvements since the date mentioned, by which the quality has been improved and the production increased. There are yet in use in both this country and America a considerable number of hand-looms, chiefly employed with jacquard attachments on the production of ingrain and damask carpets.

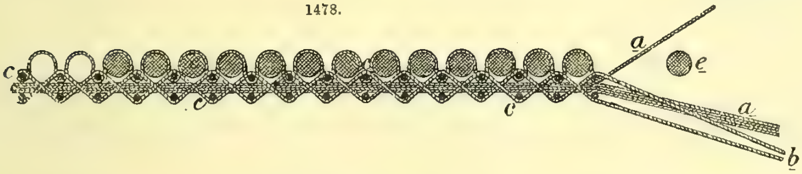
Mechanicians in the field of carpet manufacture had a comparatively easy task before them. The power-loom with the jacquard attachment was ready to their hand in a very perfect condition. All it required was that its different parts should be strengthened and adapted to withstand the shock of driving home the filling in a heavy fabric like a carpet. This was easily accomplished, as was the addition of a strong pacing or warp-delivery arrangement and taking-up motion. The principal part requiring to be invented, and which is peculiarly an adjunct of the pile-fabric loom, was an automatic method of inserting and withdrawing the wires by which the loops of the pile are formed. Another important point was to combine this apparatus with the mechanism of the power-loom as employed for weaving either plain fabrics or those with jacquard patterns. After some difficulty, this was successfully accomplished, and since that time the carpet industry has rapidly extended in this country, and of late years also in America.

Figs. 1477, 1478, 1479 illustrate the construction of the fabrics known as tapestry, Brussels, and velvet-pile carpets. The first is a longitudinal section of the tapestry carpet, with the shed open for the insertion of a looping wire. It will be observed that the warp consists of three distinct portions. The pile-warp a is usually composed of printed worsted yarns, the design being printed in such a manner that when woven and piled in the fabric, a pattern shall be the result. The next is the body-warp *b b′*, usually of linen or cotton yarns; of late years, the latter have come to be preferred, as it is found from their greater pliability that they wear better than linen warps for backs. This warp binds the whole fabric together, being interwoven with the weft, the threads of which are seen in section at *c*, forming two series, one under and one over the third warp *d*. This warp is introduced to give thickness or substance to the fabric, and in tapestry is generally composed of some softly-spun, cheap material which will allow the other portions to embed themselves in it,

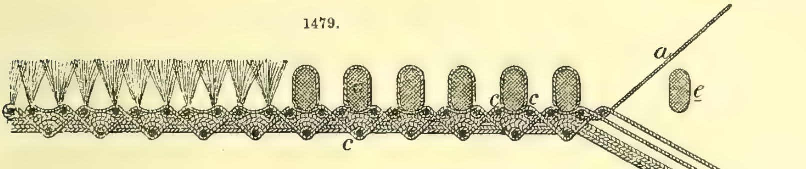
1477.



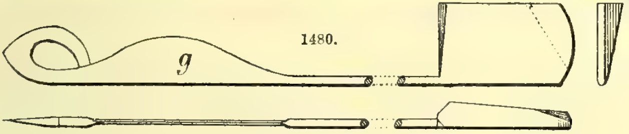
1478.



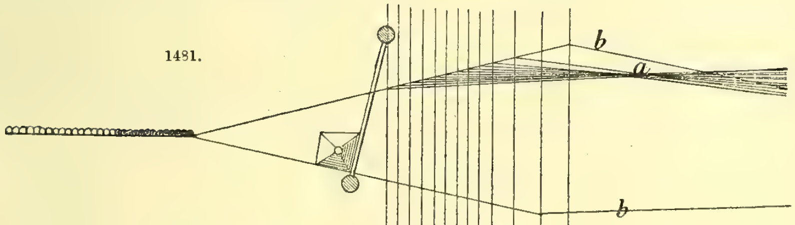
1479.



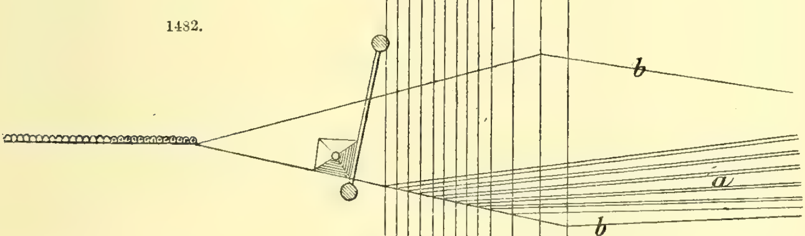
1480.



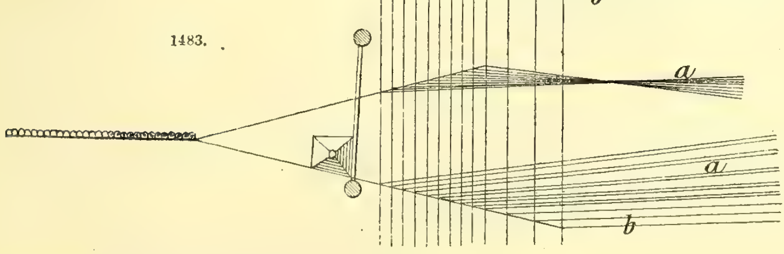
1481.



1482.



1483.



so that during wear the pile-threads will not easily allow themselves to be drawn from their position. The threads of this warp neither rise to the front nor descend to the back of the fabric; being introduced only for the purpose before named, they are retained in the centre of the fabric. The threads of the pile-warp *a* are never taken below the filling-warp *d*, consequently they never appear at the back of the fabric, which fact explains the absence of coloured threads at the back of a tapestry carpet, by which inexpert people are best enabled to recognize its true texture. In weaving, the whole of the pile-threads are lifted and lowered at once; when raised, it is for the purpose of admitting the introduction of a new wire as seen at *e*. When lowered, one portion of the body-warp *b* is raised to form a shed for the weft, which has the filling-warp *d* raised to form a different shed for its return. The course of each warp and its function in the construction of the web can easily be traced from the diagram. After a sufficient length of the fabric has been woven to prevent the tension on the pile-warp drawing down the loops, the wires are withdrawn, and are then ready for renewed use.

Fig. 1478 represents a similar section of Brussels carpet with the shed in like manner open for the insertion of a new wire. The texture of the fabric is very similar to the preceding, so far as the interweaving of the threads goes. The body-warp *b* serves the same purpose as in the preceding case, but is differently composed, there being three, four, or five times as many threads in the pile-warp as before, and only $\frac{1}{4}$ or $\frac{1}{5}$ of these are raised at one time to form the pile. The remainder take the position of the filling-warp in the tapestry carpet. In Brussels carpet, the pile-threads are individually of one colour only, and not printed to form the design as in tapestry, the jacquard lifting the coloured threads to form loops as required by the nature of the design. Some of the pile-threads being required to be raised very frequently, and others only at long intervals, necessitates the use of a creel or bank in which bobbins containing only one thread each are placed, in this differing from the tapestry carpet. The pile-threads are all wound upon one beam. The embodiment of such a large proportion of the pile-threads in the filling-warp causes the colour of the threads to appear at the back—indubitable evidence of its being a true Brussels texture.

Fig. 1479 illustrates the construction of the web of a velvet or cut-pile carpet, which is almost identical with the Brussels in texture, except that two threads of weft *c* are used for binding the pile. The pile wires *e* are also elliptical in the form of their section, thus making a deeper pile when inserted; and, being furnished with a knife-edge at the distant extremity, cut the loops when withdrawn, as illustrated in Fig. 1479. Fig. 1480 is a full-size illustration of the wire used for weaving a cut-pile fabric, *g* being the blade or cutting end.

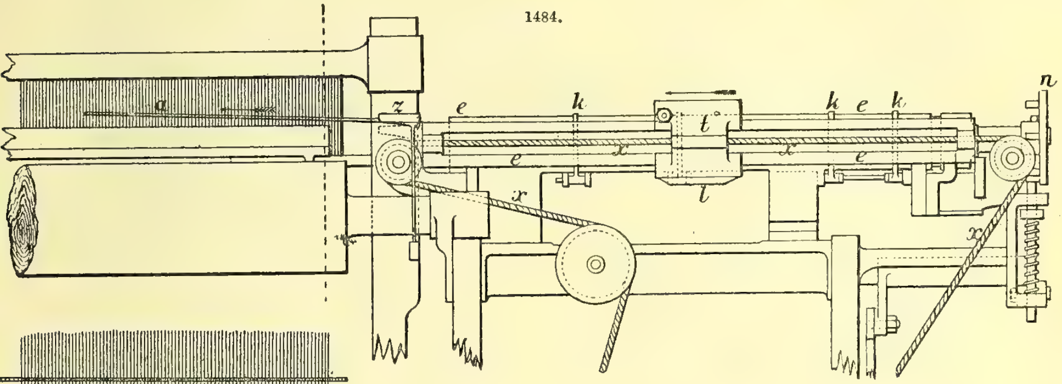
Figs. 1481, 1482, 1483 exhibit the order of "shedding," by which the Brussels carpet is composed. Fig. 1481 is for the passage of the shuttle and the reception of the weft. All the pile-threads *a* have been raised, and also one-half of the body-warp *b*, the remainder being left down. The shuttle is then thrown through the open shed, leaving the pick of weft that shows itself at the back of the fabric. The next movement opens the shed shown in Fig. 1482, which is also for the passage of the shuttle, and the reception of a thread of weft. In this, all the pile-threads are down, and the two portions of the body-warp *b* remain as before, the shuttle traversing the shed again puts in the top pick or thread of weft, which is the binding pick by which the loops formed upon the wire last inserted are tied securely in position. Fig. 1483 shows the last shed necessary for the formation of this particular fabric. It is for the reception of the wire used in the formation of the loops; all the body-warp threads *b* are left down, also all the pile-threads *a* not required for the design; those needed to form the pattern are lifted by the jacquard, and, on the insertion of the wire, are retained in loops by it until a binding thread of weft has tied them down. To keep them securely fixed, the wires are left in until a sufficient length has been woven to prevent them being drawn backwards.

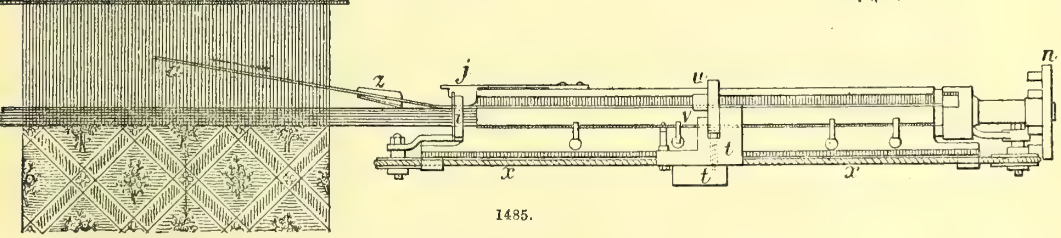
As observed before, the problem to be solved in connection with the carpet-loom was the invention of an automatic plan of inserting and withdrawing the wires to form the loops. As in connection with nearly all other mechanical inventions, the present approximately perfect system has been the result of growth, the first rude effort serving as the foundation upon which succeeding inventors have built. An arrangement was first constructed by which from a bundle of wires a single one was successively drawn as required, and, by means of a pair of nippers, fixed at the end of a reciprocating rod, was carried into the shed; and after having been woven into the fabric and subsequently withdrawn from the loops, the wires were returned by the hand of the weaver to the bundle. An improvement followed this by which the whole operation was rendered self-acting. This consisted of dropping wires successively from a hopper into a longitudinal groove in a rod, which was carried into the shed in guides, and was then caused to make a half-revolution by means of a screw-incline on the rod, by which the wire was dropped into its place in the shed. The wires were successively withdrawn from the fabric by reciprocating nippers, and carried up again into the hopper by endless chains. The next step was to simplify this by a plan of placing the wires separately in a groove from which in succession they were pushed into the shed, and being constructed with a hook at the back end, each was subsequently, at the proper moment, withdrawn and transferred to the feeding-trough for use again.

In these first attempts, various means were used to support the forward extremity of the wires, as it was assumed that they could not be otherwise held with sufficient rigidity to secure their correct insertion without being thus sustained. This plan was, however, afterwards abandoned, as by the aid of further improvements it was shown to be unnecessary.

Some years ago, W. Weild, of Manchester, invented a system of inserting the wires in carpet-looms which, with subsequent improvements, has remained in favour up to the present time. This plan is known as the roller wire-motion, and is fixed to one side of the loom. Figs. 1484, 1485, 1486, show front elevation, plan, and section of this attachment. In the two first figures, a wire *a* is shown being inserted into the shed of the fabric. In the plan, Fig. 1485, is shown a portion of the woven fabric, and the reed with which the weft and the wires are pressed to the fell of the fabric—the part last woven. Fig. 1486 is a transverse section of the roller *r* in its casing *e* and the slide *t* for inserting and withdrawing the wires. The roller and its casing *e* are rather longer than the width of the carpet to be woven, and the upper part of the casing is cut away through the extent of one-sixth of the circumference of the roller, as shown in the figure. In the surface of the roller *r* six longitudinal grooves are cut, of a width and depth corresponding to the diameter of the wires. The roller enclosed in its case is fixed with its end about 9 in. from the edge of the carpet, and with its upper surface parallel and in the same plane as the "fell" of the carpet. At the end of the casing nearest the warp, a recess is formed between the end of the roller *r* and a hoop *i*, Fig. 1485, concentric with the roller. In this recess, which extends through $\frac{1}{6}$ of the circumference of the roller, the heads of the wires are held when inserted in the fabric as shown in the plan. The hoop keeps the heads of the wires down in their places, and prevents them being pushed too far into the warp, and at the same time prevents their being withdrawn before the proper moment. A projection upon the end of a spring *j* attached to the side of the casing keeps the heads of the wires erect, pressing them against each other, and against the end of the recess during the whole time that the wires remain inserted in the carpet. At the opposite end of the roller, is a projecting collar formed all round the roller, between one end of the casing *e* and a hoop carried by a bracket. This collar contains six grooves in which to receive the heads of the wires, and retain them in their correct radial position, whilst being carried round by the roller, in the direction shown by the arrow in the sectional view. When the roller is stationary, two of its six grooves are opposite the two extreme wires in the recess *i*, Fig. 1485, one being opposite the wire last inserted, and the other opposite the wire next to be withdrawn from the fabric. The other four grooves *h* have each a wire lying in them as shown in the section, so that each time the roller makes $\frac{1}{6}$ rev., one wire is brought round to the place for insertion into the shed of the warp, and the wire last drawn from the carpet is carried away.

1484.

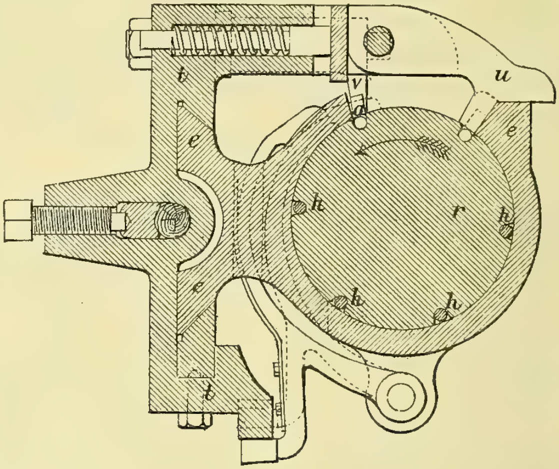




1485.

On the front of the casing *e*, a slideway is formed parallel to the axis of the roller *r*, upon which is fitted a slide *t* carrying a finger *u* for inserting the new wire, and the pawl *v* for withdrawing the last wire. The finger is hinged upon the slide *t* by a spring-joint, as shown in the section, so as to be steadily held when either up or down. When down, as in Fig. 1484, it slides against the inserting edge of the casing *e*; and a recess in the extremity of the finger fits over the head of the wire that is being inserted, so that, as the slide *t* traverses inwards towards the carpet, the finger *u* pushes the wire forwards into the shed, holding it down into the groove of the roller. When the slide arrives at the inner end of its traverse nearest to the carpet, the pawl *v* is tripped up by the head of the wire next to be withdrawn, and drops on the inner side of the head, and the wire is then withdrawn by the pawl during the outward traverse of the slide *t*. In order to prevent the wire, whilst being withdrawn, escaping from the groove in the roller, several curved fingers *k* are used, jointed to the under side of the casing. The ends of these fingers cover the groove which receives the wire withdrawn, as shown by the dotted lines in the section, and each finger is pressed down upon the roller by a spring acting against the side of the hole through which the finger passes in the casing *e*. These fingers have to be lifted out of the way successively, in order to allow the head of the wire to pass; and this is done by a double incline *l* upon the bottom of the slide *t*, which acts upon the projecting tail of each finger in succession during the traverse of the slide.

1486.



The slide receives its traversing motion from a rope *x*, which is secured in a hole in the slide by a block and set-screws, Fig. 1484; this rope passes over guide-pulleys at the ends of the roller-casing *e*, and then downwards to a larger pulley not shown in the drawings, to which the two ends of the rope are secured. The shaft of this pulley carries a pinion-gearing with a toothed sector, which is centred at the top in the framing of the loom, and is worked backwards and forwards by a drum-cam upon a shaft behind. This cam is shaped to produce a quick forward traverse of the slide *t*, so as to insert the wire quickly whilst the shed is held open for it; but it gives a slower backward traverse to the slide, so as to withdraw the wire slowly, having more time in which to perform this operation, as a wire is inserted only in every third shed.

After each wire has been inserted, the wire roller *r* is turned round through $\frac{1}{6}$ rev. in the direction of the arrow, by means of appropriate mechanism. A cam upon the end of the cam-shaft gives motion to a lever, oscillating upon a centre in the framing of the loom; and the other end of this lever has a forked pawl jointed to it, which is kept pressed by a spring against the pins in the disc *n*, secured upon the end of the wire roller. The wire is held steady by a T-piece sliding vertically, and which is pressed upwards by a spring against the pins in the disc *n*. The wires lying in the grooves of the roller, previous to insertion into the fabric, project 2–3 in. beyond the inner end of the roller; and if the point of the wire went straight forwards as pushed from the roller groove, it would be impossible to make it enter the shed correctly, as it would then be so close to the fell of the fabric, or junction of the warp threads forming the fell or angle of the shed, that the point of the wire would inevitably catch these threads. The wire is consequently sprung or deflected upwards, as shown at *a*, Fig. 1485, by means of the short grooved guide *z*, through which the wire passes as it is pushed out of the roller groove. This guide is fixed upon the top of a vertical rod which is moved up and down by a lever actuated by a cam, and when the wire has been pushed nearly through the shed, the guide is lowered into the position shown by the dotted lines in Fig. 1484, to be out of the way of the wire at the moment of its being driven up by the reed, after which it is lifted again to be ready for the insertion of the next wire. The springing of the wires by the guide in directing them into the shed might at first sight appear objectionable, but the amount of this bending does not exceed what they will recover by their own elasticity, and the experience of working during several years has proved it to be of great advantage, because the bending stiffens the wire and makes its point steadier whilst passing through the shed. Besides this, in consequence of the angle at which the guide causes the wire to enter the shed, the point of the wire comes into a wider part of the shed, the further it passes through the shed; and thus as the unsteadiness of the point of the wire increases with the greater length unsupported in the shed, more space is allowed for its vibration without risk of its catching the threads forming the shed.

Owing to the position of the roller wire-motion at one side of the loom, the shuttle-box on that side has to be made detached from the ordinary sley or batten. It is therefore carried upon separate sley-swords, which oscillate upon a shaft coinciding with the shaft of the ordinary sley. This loose shuttle-box is actuated by a cam upon the crank-shaft of the loom, which acts upon a roller in a rod jointed at one end to the shuttle-box, the other end of the rod being slotted to slide upon the crank-shaft as a guide. The cam is shaped so as to actuate the loose shuttle-box in such a manner that it will come opposite to the sley and have a motion identical with it at the time the shuttle is passing into the shed. The description of this ingenious attachment to the carpet-loom is substantially that of the inventor. On good looms, to which it has been added, a production of 42 yd. a day as an average is easily attainable, including stoppages.

During the past few years, several important improvements in the carpet-loom have been introduced, the object of which has chiefly been to simplify the mechanism and facilitate production. The Bigelow loom, the first successful power-loom for the manufacture of carpets, was an American invention, and we are indebted to that country also for several recent improvements of an important nature.

The standard make for Brussels carpet is 8 wires for 1 in. of length and 27 in. of width of carpet. The difference in the work involved and in the quality consists in the greater or less number of coloured threads used in the pile-warp for forming the pattern; in the best carpets, these amount to 1300, all of which are to be brought up to the surface in turn and kept in order. About $\frac{1}{5}$ of these must be lifted by the jacquard at each insertion of a wire, to ensure its being completely covered all across the fabric. To the above threads have to be added those of the body-warp, about 400 in number, thus bringing up the total in a good Brussels to about 1700, each of which must have a separate mail or cord, so as to permit of its being picked up individually whenever required by the design.

In the manufacture of carpets, as in other goods, great changes have been produced by the extension of our commerce. English wools, such as britch, saycast, matching, neat, brown drawing, and other sorts were formerly the main bulk of those consumed. These, however, would now be too expensive, and consequently have been superseded by foreign wools, such as E. Indian, Persian, and other barbarian wools, i. e. wools from unimproved breeds of sheep, many of which possess very good qualities for carpet purposes. Oporto wool is in high estimation, yielding a soft, lustrous yarn, which covers the grounds very well, and is extensively used for medium shades of colour, and for browns, yellows, &c. Best whites are made from high class English wool, whilst low whites are obtained from an inferior quality of our home produce. The former are also used for white shades and light drabs; a medium quality is used for general purposes, and is suitable for such colours as reds, browns, and most dark shades. For black grounds, it is most economical, and also satisfactory as regards quality, to use a level, full, and well-spun grey yarn. Less dyestuff is needed to get the required shade, which, when it is obtained, is as solid and durable as that upon a white yarn, though the dyeing will have cost 20 per cent. less.

The quality of carpet pile-yarns is judged high when it is free from lumps and kemps, and is evenly spun in every respect. It is far the wisest course, though not quite a common practice, to scour samples of all yarns intended to be bought, because this reveals the faults, especially when unevenly spun or twisted, which causes it to "cockle" or twist up, arising from the strands having shrunk unequally; this fault gives much trouble in after processes. When the sample hank has been scoured, it should be compared with that in the grease by extending it upon the hand; if it has shrunk very much or has "cockled," it will not prove a satisfactory yarn in working, and ought to be avoided. It is also desirable to carefully ascertain the diminution of weight after scouring, because much loss may accrue from buying yarns heavily laden with grease. The strength of the yarn is always an important matter, and care should be taken to have it of a quality equal to the work expected from it. Both in this respect and in regard to fineness, it should be tested frequently; in the latter, in every delivery when the yarn is purchased from outside. When the test shows it to be within a quarter of a count of the nominal fineness, it is regarded as correct.

Scouring the yarns is simply the process of clearing them from the oil and grease of previous stages, and is ordinarily performed in a "wash," or bath of water in which soap or honey soda has been dissolved. Several special methods have been adopted for doing this efficiently, but these require no particular description, as the object of all is to clear the yarn perfectly. The system by which this result can be secured most completely is manifestly the best one, and any plan falling short of this is not to be adopted. Well-cleared yarns take the dyes more perfectly than others, and yield a better result.

For dyeing purposes, copper, wooden, or stone vats are usually employed. Of these, perhaps those of stone are most eligible, for they do not absorb and retain the colours to the detriment of succeeding baths, as do those of wood, and are rarely if ever affected by acids, as is sometimes the case when they are composed of metals.

Several hank-dyeing machines of considerable merit have of late years been introduced into the various textile industries wherein dyeing is a branch of the process, and these have found favour amongst carpet-manufacturers, because of the greater uniformity of colouring obtained by their use. The hanks of yarn are by means of the machine simultaneously immersed in the dye-bath, and in like manner withdrawn when required, all being thus uniformly exposed. A recent improvement also enables the hanks to be automatically wrung, which ensures every hank being twisted exactly alike, whereby the liquid dye is equably expressed, and evenness of shade is secured.

By these various improvements, carpets are now produced, and enabled to be sold at very low prices, whilst retaining excellence of quality and beauty of design.

Besides the pile-warp, which is always composed of worsted, there are three other varieties of yarn that enter into the composition of a carpet: the "chain," the "shute," and the "stuffer." The former is amongst manufacturers preferred to be of linen, for the reason chiefly that it gives weight and firmness to the fabric in a superior degree to cotton, though the latter is a better wearing article when of good quality, and is often if not always more economical. When linen warps are used, the sizes are usually 5¼, 5½, or 6 lea good tow yarns, the middle number being the most common. In cotton, the numbers are usually 8's 9's and 10's 3-fold, the first prevailing as regards quantity consumed. Jute has been tried, but has not been found to be a satisfactory substitute. For the shute or weft of the fabric, linen is always used, as, not requiring to be so hard spun as the shorter fibre of cotton, it is more easily embedded in the warp threads, and covers them in a superior manner. The stuffer warp is composed of low cotton-waste yarns, called "bump" yarns, the single thread of which runs about 70 yd. to 1 oz. Its purpose is to stuff or fill tapestry carpets, hence its name. This class of yarn is the best known article for the purpose. It is produced principally in the neighbourhood of Oldham. The chief requisite of quality is evenness.

Chain, shute, and stuffer yarns are all sized before being used. The "sizes" employed are composed of different materials, such as horn piths, old pickers, glue, and one which is glue in an unfinished state. These are preferred by individual manufacturers for different reasons, some of which can hardly be distinguished from sentiment or prejudice.

Designs.—The most important part of carpet manufacturing is to secure good designs. In 9 cases out of 10, if not in 99 out of 100, a carpet is sold by the design, the intrinsic quality being taken into consideration only as a secondary matter. Of course, the best designs are always utilized for the highest qualities, because they are most likely to be selected by consumers possessing taste and culture, which qualities are usually found associated with fair means or social position. Large establishments possess designing departments under the superintendence of first-class men. Smaller establishments procure their patterns from professional designers, who make designing a separate business and sell their productions to all comers. Schools of art have done much to improve taste and increase competition in this branch, and it is not difficult to obtain excellent designs in this manner.

Another important requisite of this branch of the art is that of being a good colourist. A capital design may easily be spoiled by incongruous or inharmonious colouring. When a good design, however, is secured, it is desirable to make the most of it, which can often only be done by bringing it out in from three to ten or twelve colourings, in order that it may harmonize readily with a great variety of surroundings. It is frequently discovered also that the designer's arrangement of colour can by a slight modification be improved upon, and this is sure to show itself under this varied treatment. To most establishments is attached a man whose duty is to try the effect of slight alterations in the colourings, and improve them where possible. An indifferent design when skilfully coloured is often more successful in striking the public taste than a better one where the colouring is not so well done.

Products.—Having brought under notice a condensed view of wool as a raw material, showing its nature, variety, sources of production, and chief applications, and having followed it through the various processes of the three principal industries of which it forms the basis, and in which it is transformed into articles of utility, a brief enumeration of the varied products may be permitted.

Woollen goods is a comprehensive phrase, and includes all those articles manufactured from carded wools by the processes previously described. At the head of this class, deservedly stand the celebrated broad-cloths of the West of England. In the last century and during the first half of the present one, scarcely any articles except broad-cloths, plain woven fabrics, and Kerseymeres or twilled fabrics, were available for the consumption of the male sex. These were uniform in colour, variety of colour and shade being all the changes available to meet the demands of fashion. The first-mentioned article has undergone no important change for centuries, except approaching greater perfection of finish, arising from improved methods of manufacture and the introduction of finer wools. The industry is widely spread, but in no centre are the articles produced by the West of England surpassed in the best and most essential qualities of a good fabric,—thickness, solidity, suppleness, fineness, and beauty. This has been amply demonstrated at the numerous international exhibitions that have been held during the past 20–30 years, and which have permitted comparison to be made with the productions of other nations. In the best goods, the highest priced Silesian or Electoral wools are almost exclusively employed. A lighter class of these fabrics are made in Germany, the beauty and excellence of which can hardly be surpassed. Those of France also possess high qualities. America scarcely produces any broad-cloths.

A great change was inaugurated in the manufacture of cloths in 1834 by the adaptation of the jacquard attachment to the production of fancy woollen cloths. This was first done by Bonjean, a woollen manufacturer of Sedan. He conceived the idea of modifying the plain cloths hitherto universally made, by uniting upon the same stuff different tints or patterns of tissue, which he was enabled to effect by means of the jacquard. It was soon evident that there could be no end to the variety of patterns that could now easily be produced, and that fancy could henceforth be allowed free play. From this fact, the name of "fancy" woollens was derived. This process was soon extensively imitated in France, Germany, England, and America. In the last country, George Crompton, a Lancashire emigrant, having his attention drawn to these goods, invented a loom specially adapted to their production, and which, known by his name, has since been extensively introduced into the trade. Similar looms have been devised by other inventors, and a large trade in these goods has been created in all countries possessing an established woollen industry. As a consequence the products are innumerable, and in style and pattern vary with the changing seasons.

Flannel manufacture is a considerable branch of the woollen trade. Flannel is cloth which only passes through two or three of the processes subsequent to weaving. Flannels are extensively worn by all classes of society, both male and female, for under-garments, for which they are exceedingly well suited. They are extensively produced in England, Germany, France, and America. A comparison of English and American flannels shows that the latter have the yarns rather more closely twisted or spun, to prevent or diminish shrinkage. Flannels are made plain, twilled, dyed and printed, and in unions of cotton warp and woollen filling, or otherwise, as more frequently of late, the cotton being introduced in the fibrous state, and mixed with the wool in the earliest stages. A high class article is obtained by the employment of a silk warp, and yarns from a high grade of wool. Blankets for bed-wear are a heavier description of flannel, and constitute an extensive manufacture.

Worsteds, the next great class of textures of which wool forms the raw material, offer much greater diversity than the preceding. The first point of difference is that the yarns are composed of combed wools, and the fabrics are rarely shrunk in any stage of the manufacturing process. Thirty or forty years ago these products almost exclusively appertained to female uses, as did woollens to men's purposes. Since that time, however, great changes have taken place, and the softer sex have successfully claimed a large portion of the products of the woollen industry, whilst on the other hand men have occasionally adopted worsted goods for wear, especially in coatings. As a division, this branch is equal to if not superior in importance to the woollen manufacture.

The fabrics produced in worsteds are almost infinitely varied. The names, however, by which they are distinguished are purely fanciful in most cases, and afford no clue either to the class of the material of which they are composed, or the method of fabrication. These names are usually given by the manufacturer or merchant who first introduces them, and if they should prove successful, it is not often long before the name is attached to some other fabric of quite another character, or at least a degraded imitation. To suit the public craving for variety, old fabrics are continually reappearing under new names; and with some slight modification still more frequently. Hence the great confusion which exists amongst distributors and the public, who are bewildered thereby, owing to the want of some rational or scientific system of classification.

The texture, "weave," or *armure* as the French call it, offers the best basis for a classification of woven goods, and might, paying due regard to the other elements of the fabric, form also the basis of a system of scientific nomenclature, though it is doubtful whether such could ever become a substitute for that popularly current. The texture or weave means the order of the interlacement of the warp threads: the French designation *armure* means the system of harness with which the loom is furnished or armed. There are four of these systems which may be regarded as fundamental, and which are employed to produce nearly all the varieties of simple fabrics. In the first or "taffeta" weave, there are only two harnesses, forming a simple interlacement of the threads, such as used in the production of plain broad-cloth, calico, or *mousselines-de-laine*. In this, alternate threads of the warp rise together, the intermediate ones being depressed to form the shed for the passage of the shuttle and the introduction of the weft. When a thread of the latter has been put in, the elevated threads descend, the bottom ones rise, and another transverse or weft thread is inserted, the previous one having been driven home by the sley. The next is the "twilled" or

"Batavia" weave, in which four harnesses are employed, and in which the four leaves of the harness ascend in successive order, producing a pattern upon both sides of the fabric, which takes the form of a diagonal line across the width, the pattern on the back running in an opposite direction to that on the front. The third is the "serge," a 3-harness twill, the effect being a similar pattern to the above, but upon one side only, the back being in this case plain. The fourth is the "satin" weave, and is produced by five or more harnesses; the effect in this is to bring the weft threads most conspicuously to the surface. Many of these are often combined with one another, or with "fancy" weaves, one of which is the leno, in which the warp threads are made to half twist round each other, and are fixed in that position by the weft. By these means, and the combination of various materials or colours, numerous and widely different effects are produced.

The following table of worsted stuffs composed of the finer classes of combing wool will prove instructive, and illustrate the foregoing observations. As will be seen from the names, the first portion of the list is chiefly French, and is from Alcan. The later is English. Both are, however, common in many cases to England, France, and America.

Name of Fabric.	Weave.	Warp.	Weft.	Remarks.
Manteau	Taffeta	Carded wool	Carded wool	.. ..
Reps	„	Wool	Fine wool	Made of long combing wool, and wide for furniture.
Turquoise	Serge	„	Wool	Woven in checks and Scotch plaids, the warp having a serge *armure* of 2 and 1, and the weft a serge *armure* of 1 and 2.
Merinos	Batavia or double twill.	Fine wool	„	Made of 8–50 picks per *centim.*; formerly very popular, but latterly quite gone out of favour.
Cashmere	Single or one side twill. Serge.	„	„	Made like the above in quality. A fabric yet in considerable favour.
Drap d'été	„ „	„	„	The warp double.
Mousselines-de-laine	Taffeta	„	„	.. ..
Moulletons	Satin	Wool	„	.. ..
Poplin	.. ..	Silk or wool	English wool	Poplins are either silk and wool, all wool, silk schappe and wool, cotton and wool, or fancy printed. The poplin or corded effect is produced by the thickness of the weft threads.
Barége	Gauze or open taffeta.	Cotton	„ „	Generally a printed fabric.
Challis	„ „	Silk grége	Merino wool	Differs from barége only in the materials.
Grenadine	„ „	Silk grége, organzine, or cotton.	English combing wool.	The weft is much twisted and gased; a kind of close barége.
Llanos	„ „	Cotton	Mohair, or mixed with silk.	The warp composed of 3 threads, white; while the weft is violet, blue, or black, which give reflections to the stuff.
Toile de Saxe	Taffeta	Cotton, single or twofold.	English wool	Peculiar finish.
Cretonne	„	Cotton, double and twisted.	Wool	Has a peculiar elasticity, due to the hard spun warp.
Jupons	„	Single cotton	Carded wool	.. ..
Vode	„	Wool	.. ..	For réligieuses.
Valencias	„	Silk schappe	Combed wool	.. ..
Damask	Figured or fancy	Wool or silk	Wool	Furniture uses.
Bolivar	Taffeta	Wool	„	A light flannel made in grey, or in all varieties of colours.
The following are chiefly English,—				
Delaines	Taffeta	Cotton	Medium wool	Printed.
Baréges	Gauze	„	„	An open weave.
Reps	Double threaded taffeta.	„	„	Printed.
Cashmeres or Coburgs	Twilled	„	Merino wool	Made in imitation of Cashmeres d'Écosse, all wool.
Alpaca, formerly Orleans.	Taffeta	„	Long lustre wool	Weft originally of alpaca.
Brilliantine	„	„	Fine mohair	Usually black; the warps dyed before weaving.
Lustres	„	„	Lustre wool	An alpaca of lower grade.
Fancy alpaca	Figured fancy weave.	„	„	.. ..
Brocade	Taffeta	„	„	A corded ground with a figure.
Poplin	„	„	Long combing wool	Corded effect produced by thick weft.
Debaige	„	„	Weft made from black and white wool mixed.	.. ..

This list, were it required, could be greatly extended, but the examples given will suffice. During the past few years, worsted fabrics have been quite out of vogue as dress materials, the demands of fashion requiring softer fabrics than can be produced from the long English wools. The worsted industry has therefore suffered from considerable depression, and this has seriously depreciated the price of English wools. The trade is now in a transition state, a considerable number of the largest capitalists therein being engaged in altering their machinery to manufacture fine short wools consumed in the production of soft all-wool goods.

Besides Kidderminster, Brussels, and tapestry carpets, sufficiently described already, there are several other varieties which call for brief notice. Persia may be regarded as the birthplace of the carpet manufacture, and its productions have formed models for the imitation of all countries. Persian carpets or rugs are chiefly made in Kurdistan, Khorassan, Feraghan, and Kerman, each district producing a distinctive style and texture. The finest are those of Kurdistan. In these carpets, the most perfect taste is generally manifested, the pattern never representing flowers, bouquets, or other objects, thrown up in relief from a uniform ground, as in European and American styles, but wrought so as more to represent a layer of flowers strewn under the feet of the observer. They are furnished with borders always well accentuated and of brighter colours than the centre. Feraghan carpets are not unlike those of Kurdistan, but are less close and of simpler pattern. They are cheaper, and consequently in more general use. Khorassan carpets are superior in texture to the last, and usually more realistic in patterns. The carpets of Kerman are still more realistic in style than those of Khorassan, and in value approach those of Kurdistan. In form, Persian carpets are usually rather long and narrow, which renders their manufacture easier, and suits the shape of the rooms in which they are to be laid. Of all carpets, these are perhaps the most purely hand-fabricated, all being made without even the simplest machinery, the loom merely consisting of a frame on which the work is stretched. The woof consists of short threads interlaced with those of the warp by the fingers alone, and when a cross thread has been completed, a comb is inserted into the warp threads by which the weft is pressed or driven home. The pile is formed by merely clipping the protruding threads until an even surface is obtained. The weaver sits with the reverse side towards him, and depends upon his memory for the formation of the pattern. Persian carpets are admittedly superior to all other oriental products of the same class, being distinguished by their subdued tones and harmony of colours. Certain forms are repeated in all designs, which clearly mark their national character.

Turkish or Smyrna carpets, now extensively imported into the west of Europe, are in the best specimens generally designed with a flat border, or in other words without perspective, of flowers of the natural size, and with a centre of larger plant forms conventionalized, often to such an extent as to obscure the forms. The colours are negative shades of a medium or half tint, tending rather to dark, and possessing little of contrast, the result being a sombre effect. Many of those exported to Europe and America are of a degraded kind, being manufactured to meet the foreign demand.

Indian carpets are made in large single pieces adapted for covering broad floors. They usually possess a great variety of colour, but so evenly distributed, and each artistically balanced by its complementary and harmonizing hue, that the effect produced is exceedingly agreeable. The forms generally consist of highly conventionalized flowers and plants geometrically arranged.

The above classes fairly represent the productions of this description of article that have been the outcome of Asiatic phases of civilization, and afford a considerable contrast to those which may be deemed characteristic of the West.

The carpet industry in this country is widely distributed. Its chief seat, however, is the town and district of Kidderminster, which has numerous and extensive manufactories where tapestry, Brussels, Wiltons, Axminsters and other carpets and rugs are produced. Isolated establishments also exist in several of the southern counties, such as at Crayford in Kent, and Crewkerne in Dorset. In Lancashire, Rochdale is the chief if not the only place making carpets. In Yorkshire, it is an extensive industry, Heckmondwike, Halifax, Leeds and other places sending large supplies into the market. In the city of Durham, there is a considerable manufactory. In Scotland, the trade has been largely developed, Glasgow being a chief centre. Paisley, Glenpatric, Lasswade, Stirling, Kilmarnock, Perth, Forfar and Aberdeen all possess establishments engaged in this manufacture. Aberdeen is distinguished for its "Scotch" carpets of great excellence. Dundee has obtained a reputation for jute fabrics employed for the same purpose. In the various prisons of the country, mattings for floor coverings made from coco-nut fibre (see p. 939) are extensively manufactured, which serve the purpose of carpets in many humble households.

Statistics.—According to the Parliamentary return relating to the textile industries, and which has been quoted in previous articles, it will be found that in one form or another there are a large number of establishments engaged in the manufacture of wool. These are widely scattered over the different parts of the Kingdom, though of course chiefly collected in several great centres in England and Scotland. These mills differ considerably in magnitude: thus of the 420 woollen spinning mills in England and Wales exactly half are located in the Principality, which, for statistical purposes relating to these matters, also includes Monmouth. Against these, Yorkshire has 156, the remainder being scattered over the other parts of the Kingdom. But whilst Yorkshire employs in this department 7206 persons in its 156 mills, Wales in 210 mills only finds employment for 893 persons. It will properly be inferred from this fact that many of these only spin the local production of wool, and satisfy a very circumscribed demand for the product in their respective districts. The yarn from this source is chiefly woven on domestic looms, or consumed in knitting hosiery goods.

The following tables condensed from the report sufficiently exhibit the divisions and distribution of the trade throughout the Kingdom:—

	No. of Factories.	No. of Spinning Spindles.	No. of Doubling Spindles.	No. of Power Looms.	No. of Persons Employed.		
					Males.	Females.	Total.
WOOLLEN FACTORIES.							
England and Wales—							
Factories employed in spinning ..	420	501,952	38,822	..	6,422	4,316	10,738
,, ,, weaving ..	65	..	..	2,917	1,715	2,188	3,903
,, ,, spinning and weaving	786	2,236,429	212,377	47,332	41,728	48,239	89,967
,, not included in above	141	..	..	..	3,298	1,796	5,094
Total	1,412	2,738,381	251,199	50,249	53,163	56,539	109,702
Scotland—							
Factories employed in spinning ..	85	238,480	15,612	..	1,802	1,233	3,035
,, ,, weaving ..	31	..	..	2,098	920	2,415	3,335
,, ,, spinning and weaving	116	320,541	46,401	4,186	7,091	8,705	15,796
,, not included in above	14	..	..	..	270	231	501
Total	246	559,021	62,013	6,284	10,083	12,584	22,667
Ireland—							
Factories employed in spinning ..	42	10,359	732	..	250	131	381
,, ,, spinning and weaving	25	29,846	4,210	411	697	775	1,472
,, not included in above	7	..	..	..	87	35	122
Total	74	40,205	4,942	411	1,034	941	1,975
Grand total of woollen factories ..	1,732	3,337,607	318,154	56,944	64,280	70,064	134,344
SHODDY FACTORIES.							
England and Wales—							
Factories employed in spinning ..	11	11,859	3,906	..	189	128	317
,, ,, weaving ..	4	..	..	199	105	165	270
,, ,, spinning and weaving	37	71,843	5,376	1,911	988	1,108	2,096
,, not included in above	82	..	..	..	876	1,504	2,380
Total	134	83,702	9,282	2,110	2,158	2,905	5,063
Scotland—							
Factories not spinning or weaving	3	..	..	..	5	11	16
Ireland—(nil).							
Grand total of shoddy factories ..	137	83,702	9,282	2,110	2,163	2,916	5,079
WORSTED FACTORIES.							
England and Wales—							
Factories employed in spinning ..	214	1,114,774	292,613	..	13,516	22,320	35,836
,, ,, weaving ..	257	..	..	39,022	10,305	16,768	27,073
,, ,, spinning and weaving	126	934,600	141,992	37,127	22,179	30,631	52,810
,, not included in above	39	..	..	..	822	1,325	2,147
Total	636	2,049,374	434,605	76,149	46,822	71,044	117,866
Scotland—							
Factories employed in spinning ..	11	40,246	18,695	..	404	1,562	1,966
,, ,, weaving ..	41	..	..	10,714	2,140	7,896	10,036
,, ,, spinning and weaving	1	6,912	2,680	530	170	617	787
,, not included in above	2	..	..	..	165	58	223
Total	55	47,158	21,375	11,244	2,879	10,133	13,012
Ireland—							
Factories employed in spinning ..	1	288	134	..	2	11	13
,, neither weaving nor spinning	1	..	..	..	10	24	34
Total	2	288	134	..	12	35	47
Grand total of worsted factories ..	693	2,096,820	456,114	87,393	49,713	81,212	130,925

SUMMARY of the TEXTILE INDUSTRIES of the UNITED KINGDOM in which WOOL is the chief material employed.

Location.	No. of Factories.	No. of Spinning Spindles.	No. of Doubling Spindles.	No. of Power Looms.	Total Number of Persons Employed.		
					Males.	Females.	Total.
England and Wales—							
Woollen Factories	1,412	2,738,381	251,199	50,249	53,163	56,539	109,702
Shoddy „	134	83,702	9,282	2,110	2,158	2,905	5,063
Worsted „	636	2,049,374	434,605	76,149	46,822	71,044	117,866
	2,282	4,871,457	695,086	128,508	102,143	130,488	232,631
Scotland—							
Woollen Factories	246	559,021	62,013	6,284	10,083	12,584	22,067
Shoddy „	3	..	..	..	5	11	16
Worsted „	55	47,158	21,375	11,244	2,879	10,133	13,012
	304	606,179	83,388	17,528	12,967	22,728	35,095
Ireland—							
Woollen Factories	74	40,205	4,942	411	1,034	941	1,975
Shoddy „	Nil.	..	..	..	..	..	..
Worsted „	2	288	134	..	12	35	47
	76	40,493	5,076	411	1,046	976	2,022
Grand total	2,662	5,518,129	783,550	146,448	116,156	154,192	269,748

As the return, the figures of which are embodied in the above tables, was made to an address of the House of Commons of the 16th May, 1878, it follows that the information given therein was collected between that date and that when the report was presented to the House, namely 31st July of the year following. This it is well known was the severest period of the recent depression in commerce and industry from which the country is now happily emerging, and which consequently affected the returns to a corresponding extent. Also, as remarked in the return, some few manufacturers failed to supply the information required, though these were not many. Owing to improvement in trade and mill extensions since that date it will be a moderate estimate to say that the above figures will require an addition of fully 10 per cent. in every department to make them fairly represent the present (1882) productive capacity of the industry. The fact also should not be omitted to be made mention of that the return is only of establishments authorized to be inspected under the Factories and Workshops Acts, which take no cognizance of places where men only are employed, though these are few; nor of any portion of the domestic branches of these industries that yet survive in secluded localities. We have reason to believe that there is more of the latter than is suspected, but it is difficult to make an estimate. If, however, we permitted ourselves to do so, we should add about 2½ per cent. to the figures relating to the number of persons employed on the latter account. These would be found chiefly in Wales and Scotland.

Commerce.—Of wool and hair the chief raw materials consumed in the industries noticed in this article, in addition to the home product, the country requires a large supply from extraneous sources. The principal of these are Australia, New Zealand, the Cape of Good Hope, S. America, Russia, and smaller amounts from many other places. The Annual Abstract of the Board of Trade Returns for the year 1880 gives the following figures as those of our total imports of these articles for the under-mentioned years:—Of sheep and lambs' wool our imports were 460,960,907 lb., value 26,194,310*l.*, to which must be added for other kinds and flocks 2,135,772 lb., value 115,352*l.* Of goats' hair or wool, 13,566,019 lb., value 1,233,855*l.*; alpaca, vicuna, and llama, 2,548,056 lb., value 181,097*l.*; horse-hair, 27,471 cwt., value 181,215*l.*; cow, ox, bull, or elk, 85,122 cwt., value 103,482*l.*; unenumerated varieties, value 227,029*l.*; and woollen rags 41,266 tons, value 820,366*l.*, or a total value of 29,062,706*l.* Against these must be set exports of native grown and imported:—Sheep and lambs' wool (British), 17,197,300 lb., value 1,187,113*l.*; other sorts, including flocks and rag wool, 12,967,900 lb., value 546,671*l.*, or a total per contra of 1,733,784*l.*

Of manufactured and semi-manufactured articles from these industries we exported during 1880:—Of woollen (carded) yarn, 851,800 lb., value 106,922*l.*; of worsted (combed) yarn, the amount was much greater, 25,612,500 lb., value 3,237,818*l.* Of woollen manufactures:—broad-cloths, coatings, duffels, &c., plain, all wool, 10,406,400 yd., 11,430,400 lb., value 2,382,492*l.*; same articles of wool mixed with other materials, 26,509,100 yd., 28,988,300 lb., value 3,077,271*l.*; narrow cloths as in first item, all wool, 4,430,900 yd., 2,840,600 lb., value 537,933*l.*; same descriptions in mixtures, 8,653,800 yd., 5,775,800 lb., value 738,965*l.* Worsted stuffs, all wool, 17,192,900 yd., 7,083,200 lb., value 1,028,631*l.*; worsted stuffs, of wool mixed with other materials, 172,747,800 yd., 42,452,300 lb., value 6,212,525*l.* Blankets and blanketing, 6,388,700 yd., 7,453,000 lb., value 586,580*l.*; flannels, 6,697,800 yd., 2,400,300 lb., value 310,508*l.* Carpets, not being rugs, 9,328,300 yd., 14,593,900 lb., value 1,133,545*l.*; rugs, coverlets, or wrappers, No. 1,168,840, value 360,526*l.* The subsidiary branches yield the following:—Shawls, No. 736,892, value 157,803*l.*; hosiery, 320,026*l.*; small wares and manufactures of wool and worsted unenumerated, 418,312*l.*; yarn, alpaca, mohair, and other sorts unenumerated, 877,953. The total of these amounts is the grand sum of 21,487,810*l.* representing the value of our manufactured and semi-manufactured goods of which wool forms the principal ingredient.

The following figures afford a comparison of our imports of raw materials for several years past:—

Imports of Wool, &c., for	1876.	1877.	1878.	1879.	1880.	1881.
	£	£	£	£	£	£
Sheep and lambs'	23,244,554	24,203,137	22,786,563	23,282,753	26,194,310	25,825,821
Alpaca, vicuna, and llama	393,255	364,175	341,671	281,311	181,097	168,679
Goats' hair or wool . ..	729,535	983,366	752,909	743,615	1,233,855	748,083
Horsehair	202,472	157,600	131,356	114,964	181,215	—
Cow, ox, bull, or elk.. ..	175,023	263,418	62,870	55,199	103,482	—
Total	24,744,839	25,971,696	24,075,369	24,477,842	27,743,959	26,742,583

These figures, however, only imperfectly represent our supply imported to supplement our domestic production. There requires to be added the amount accruing from the importation of live animals for slaughter, dead or skin wools and hair, and the vast quantity of rags needed to swell the total required for the production of shoddy.

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(See Hair; Wool.) R. M.

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